ERDC/CERL TR-06-17

Construction Engineering
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Detailed Fuel Cell Demonstration Site Summary Report

Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms

J. Michael Torrey, John F. Westerman, William R. Taylor,
Franklin H. Holcomb, and Joseph Bush

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Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms

William R. Taylor, Franklin H. Holcomb, and Joseph Bush
Construction Engineering Research Laboratory (CERL)
U.S. Army Engineer Research and Development Center
2902 Newmark Dr.
Champaign, IL 61824

J. Michael Torrey and John F. Westerman
Science Applications International Corporation (SAIC)
San Diego, CA

Final Report

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Abstract: Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. In fiscal year 1993 (FY93), the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was assigned the mission of managing the DOD Fuel Cell Demonstration Program. Specific tasks included developing turnkey PAFC packages, devising site criteria, screening candidate DOD installation sites based on selection criteria, evaluating viable applications at each candidate site, coordinating fuel cell site designs, installation and acceptance of the PAFC power plants, and performance monitoring and reporting.

CERL selected and evaluated 30 application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to fuel cell manufacturers. At the conclusion of the demonstration period, each of the demonstration fuel cell sites was given the choice to either have the fuel cell removed or to keep the fuel cell power plant. This report presents a detailed review of a 200 kW fuel cell installed at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms and operated between June 1995 and May 2000.

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Preface

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the "DOD Fuel Cell Demonstration Program." Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERDP); the Assistant Chief of Staff for Installation Management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineer Support Agency (AFCESA).

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Franklin H. Holcomb. Part of this work was done by Science Applications International Corporation (SAIC) under General Services Administration (GSA) contract No. 5TS5703C166. J. Michael Torrey and John F. Westerman are associated with SAIC. Dr. Thomas Hartranft is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Dr. Paul A. Howdyshell, CEERD-CVT. The Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

1 Introduction

1.1 Background

In fiscal year 1993 (FY93), the U.S. Congress appropriated $18 million to advance the use of phosphoric acid fuel cells (PAFCs) at Department of Defense (DOD) installations. An additional $18.75 million was appropriated in FY94 to expand the program. The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was assigned the mission of managing the DOD Fuel Cell Demonstration Program. Specific tasks included developing turnkey PAFC packages, devising site criteria, screening candidate DOD installation sites based on selection criteria, evaluating viable applications at each candidate site, coordinating fuel cell site designs, installation and acceptance of the PAFC power plants, and performance monitoring and reporting.

Thirty DOD fuel cell sites were selected based on the following criteria:

1. Geographic diversity
2. Application diversity
3. Fuel cell utilization at site
4. Energy cost savings.

The first two criteria are related more to overall program goals; the last are typical criteria for most fuel cell evaluations. It was important for the DOD Fuel Cell Program sites to represent a cross section of both “base” (including climate) and “building” applications. It was also important to identify applications where a high percentage of the fuel cell thermal and electrical output could be used at the site to demonstrate the greatest possible benefits.

Energy savings were less important in this Program than is typical with commercial applications since fuel cells purchased by the DOD were given to the Program sites. The economic criteria for each application was to generate at least $25,000 per year in energy savings, which would essentially cover annual maintenance costs. This would enable the fuel cell to pay for itself once the responsibility for maintenance was turned over to the base (after approximately 5 years).

The program followed a consistent approach for selecting sites, designing and reviewing installation plans, installing and maintaining the fuel cells, collecting fuel cell performance data and project decommissioning. This involved:

1. *Preliminary Screening*. Base energy data from the Defense Energy Information System (DEIS) was used to rank DOD sites by utility rates and potential fuel cell energy savings. DOD base personnel were contacted to identify their interest in hosting a fuel cell demonstration unit and to identify a preliminary list of potential building applications. The Navy and Air Force provided an initial list of candidate sites for consideration.
2. *Site Visits*. ERDC-CERL and Science Applications International Corporation (SAIC) representatives visited each base, evaluated potential fuel cell application sites and discussed possibilities with site personnel. Energy consumption and rates, hours of operation, availability of space, etc. and other information was collected during the site visit.
3. *Site Evaluation Reports*. SAIC prepared a site evaluation report* documenting site information, presenting conceptual fuel cell installation plans, estimation of electrical and thermal energy savings, and projected fuel cell energy savings. Based on the viability of the proposed fuel cell application, the base was accepted as a program site.
4. *Kick-off Meetings*. ERDC-CERL, SAIC, United Technologies Corp. (UTC) Fuel Cells (formerly ONSI Corp. and International Fuel Cells) and site personnel met to review the site evaluation report, discuss relevant issues, schedules, and any other concerns. UTC Fuel Cells collected site data for use in preparing the detailed site installation drawings.
5. *Design Review Meetings*. Detailed design drawings were submitted by UTC Fuel Cells for review by ERDC-CERL, SAIC, and site personnel. Specific issues related to the design were discussed and UTC Fuel Cells would incorporate changes to the drawings based on the input received.
6. *Acceptance Tests*. Installation of the fuel cells was the responsibility of UTC Fuel Cells. After the fuel cell installation was completed, a series of tests were performed to validate fuel cell performance. Upon successful completion, the fuel cell was turned over to the base, but operation and maintenance remained the responsibility of UTC Fuel Cells for approximately 5 years. Appendix A includes a copy of the acceptance test report.
7. *Dedication Ceremonies*. Many of the fuel cell sites held a fuel cell dedication ceremony as part of their program participation. Often, dignitaries such as Generals and State Governors were in attendance.

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* Michael J. Binder, Franklin H. Holcomb, and William R. Taylor, ERDC/CERL Technical Report (TR) 01-32/ADA389308, paa, *Site Evaluation for Application of Fuel Cell Technology: Naval Hospital—Marine Corps Air Ground Combat Center Twentynine Palms, CA* (ERDC-CERL, Champaign, IL, March 2001)

8. *Fuel Cell Operations*. The fuel cells operated for 3 to 5 years. UTC Fuel Cells was responsible for maintenance of the power plant as well as collection of fuel cell performance data.
5. *Fuel Cell Decommissioning*. At the conclusion of the demonstration period, UTC Fuel Cells was responsible for removing the fuel cell and returning the site to the its condition before to the fuel cell installation. Each of the FY93 fuel cell sites, including MCAGCC Twentynine Palms, was given the opportunity to keep the fuel cell power plant at the end of the demonstration and take responsibility for all costs and issues related to operation, performance and decommissioning.

This report presents a detailed review of a 200 kW fuel cell installed at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms. The base is located in Twentynine Palms, CA, approximately 150 miles east of Los Angeles. The fuel cell was installed at the Naval Hospital as part of the DOD Fuel Cell Demonstration Program. The fuel cell operated between June 1995 and May 2000. This report also reflects follow-up investigation of operating information accomplished after 2001.

1.2 Objective

The overall objective of the Fuel Cell Demonstration Program was to:

- demonstrate fuel cell capabilities in real-world situations
- stimulate growth and economies of scale in the fuel cell industry
- determine the role of fuel cells in DOD's long-term energy strategy.

This specific objective of this part of the program was to give a detailed review of the PAFC fuel cell demonstration at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms, CA.

1.3 Approach

The review process involved:

1. Collecting data from the Fuel Cell Demonstration Project at MCAGCC
2. Analyzing the data in terms of the technology's capabilities, performance, and potential for a continuing role in the DOD's long-term energy strategy
3. Compiling lessons learned from the demonstration experience
4. Making recommendations for continued/improved use of the technology at DOD installation.

1.4 Mode of Technology Transfer

Results of this work will be forwarded directly to the funding sponsor and to the participating installation. This report will be made publicly accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

http://www.dodfuelcell.com

2 Project Overview

This chapter reviews the timeline of events and the project participants involved in the fuel cell demonstration unit for the Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms.

2.1 Project Timeline

The first formal activity related to the fuel cell demonstration unit at the Naval Hospital was a site evaluation meeting held in December 1993. Between 20 June 1995 and 20 May 2000, the fuel cell operated for 21,889 hours and generated more than 3,500 MWh of electricity. The fuel cell had its last forced outage on 20 May 2000 and the fuel cell was removed in February 2001. (No fuel cell was in operation during this time.) Table 1 lists the major events and milestones for this fuel cell demonstration unit. Chapter 4 of this report gives a more detailed analysis of the fuel cell operation and performance history.

Table 1. Time line of major events and milestones for the fuel cell at the MCAGG Naval Hospital.

Date	Event
8-9 December 1993	Site evaluation meeting held at Twentynine Palms
8 March 1994	Site evaluation report submitted by SAIC
18 March 1994	Twentynine Palms selected as demonstration site
3 May 1994	Project kick-off Meeting held at Twentynine Palms
16 January 1995	Draft design drawings submitted by UTC Fuel Cells
14 February 1995	Fuel cell design review completed by SAIC
27 February 1995	ONSI submits revised drawings
2 March 1995	Fuel cell design review meeting held at Twentynine Palms
3 March 1995	Base authorizes commencement of site construction
13 March 1995	Start of construction
16-21 June 1995	Acceptance testing performed
23 June 1995	Acceptance Test Meeting; Form *DD250* signed by Twentynine Palms
26 July 1995	1,000 hours of operation milestone
9 August 1995	Fuel Cell Dedication Ceremony
14 January 1996	Fuel cell shut down due to fleet-wide water issues
28 March 1996	Install new fuel cell stack
7 August 1996	SAIC monitoring system installed
9 August 1996	Reverse osmosis system installed; fuel cell restarted

14	July	1996	5,000 hours of operation milestone
10	March	1997	10,000 hours of operation milestone
30	January	1998	15,000 hours of operation milestone
11	May	1998	Replace heat exchangers
1	October	1999	20,000 hours of operation milestone
20	May	2000	Fuel cell shut down for final time
6	July	2000	Base requests to have fuel cell removed
	February	2001	Fuel cell removed

The time between the initial site evaluation meeting and the fuel cell acceptance test time was approximately 18 months. It took approximately 3½ months to install the fuel cell following acceptance of the installation design. UTC Fuel Cells was responsible for the installation of all 30 fuel cells installed as part of this program. GBC Electrical Services installed the fuel cell as a subcontractor to UTC Fuel Cells.

2.2 Project Participants

The successful demonstration of this fuel cell unit required the efforts of several organizations and individuals:

- ERDC-CERL had overall responsibility for the DOD Fuel Cell Demonstration Program unit installed at the Naval Hospital. ERDC-CERL was responsible for contracting with the fuel cell manufacturer, identifying all sites, managing all site evaluations, and overseeing all design, installation, operation, and maintenance activities.
- *UTC Fuel Cells* manufactured the PC25B and PC25C fuel cells used at the bases. They were responsible for manufacturing the fuel cell as well as the detailed design drawings, fuel cell installation, operation/maintenance and, if necessary, fuel cell removal.
- *SAIC* was responsible for evaluating potential building applications at each site, developing fuel cell conceptual designs, performing a preliminary economic analysis and submitting the site evaluation report for review by all parties. In addition, SAIC was involved in the detailed design reviews and participating in the design review meetings. For this demonstration unit, SAIC also conducted independent performance monitoring of the fuel cell.
- *GBC Electrical Services* was the installation contractor for this fuel cell. In addition, they performed the maintenance on the fuel cell and were involved in its removal.

- *The Naval Hospital* was directly involved in the review and approval of the fuel cell project as well as coordination of maintenance activities with GBC Electrical Services.
- *MCAGCC personnel* provided review and approval for various aspects of the project including fire and utilities interfaces.

Table 2 lists the individuals involved in this demonstration project at the Naval Hospital.

Table 2. Principal project participants at MCAGCC Twentynine Palms.

Organization	Name	Project Role
ERDC-CERL	Dr. Michael Binder Frank Holcomb William Taylor Gerald Cler	Manager, Fuel Cell Demonstration Program Fuel Cell Project Manager Fuel Cell Project Manager Fuel Cell Project Manager
UTC Fuel Cells	Joseph Staniunis Douglas Young Thomas Pompa	Installation Designer Technical Representative Installation/Maintenance Coordinator
Science Applications Int'l Corp.	Gerry Merten Mike Torrey	Principal Technical Manager Project Manager
Naval Hospital	Tiffany Monaco Patrick Dougherty C.J. Chitwood	Naval Hospital Point of Contact MCAGCC Utilities Engineer Naval Hospital
MCAGCC Twentynine Palms	Howard DeVore Stuart Hammons Luke Wren	Base Public Works Utilities Engineer Facilities Management
GBC Electrical Services	George Collard Ray Aselin	Installation/Maintenance Contractor Electrician

Appendix B lists the attendees lists for the Site Evaluation, Kick-off, Design Review, and Acceptance Testing meetings. No attendees list was created for the Dedication Ceremony.

2.3 Naval Hospital Interviews

Personnel from the Naval Hospital at Twentynine Palms were contacted to discuss their overall experience with the fuel cell demonstration. The original point of contact person, Ms. Tiffany Monaco, was involved with the project from the initial site evaluation through the early part of the fuel cell's operation. Since Ms. Monaco was not available for an interview, Mr. Patrick Dougherty, who took over as site point of contact, agreed to be interviewed.

Mr. Dougherty was responsible for facilities maintenance at the Naval Hospital. He was involved with the fuel cell demonstration from its inception and attended the site evaluation meeting back in December 1993. Mr. Dougherty expressed his approval of the fuel cell technology, but stated that he "wished that it operated more than it did." His view of the technology is generally positive and he is open to participating in another fuel cell demonstration, should the opportunity present itself.

The facility personnel conducted an analysis of costs associated with continued operation of the fuel cell, including replacement of the cell stack. The results of the analysis revealed that it would not be economically viable to continue to operate the fuel cell at the Naval Hospital. As a result, the Naval Hospital requested that the fuel cell be removed from the equipment pad following the demonstration period. Figure 1 shows the fuel cell installation. Figure 2 shows the fenced area where the fuel cell had been installed. The tall tank at the back left corner was for storing fuel cell thermal output. The area is now used for storage of miscellaneous items.

Figure 1. Fuel cell installation.

Figure 2. Fuel cell site after removal.

3 Fuel Cell Design and Installation

This Chapter reviews the basic fuel cell design and installation procedures used for the Naval Hospital fuel cell at Twentynine Palms.

3.1 Fuel Cell Building Application

The Naval Hospital building opened in early 1993, the same year that the site evaluation meeting was held. The hospital is a 190,000 sq ft facility with 39 patient beds and various specialty clinic facilities. The facility operates 24 hours per day. In addition to the hospital, a barracks was considered as a possible candidate site for the fuel cell. However, the barracks was eliminated from further consideration because it was scheduled to be torn down within a couple of years. ERDC-CERL TR 01-32 provides more details about the site evaluation.

3.2 Conceptual Installation Design

Based on the initial site evaluation meeting in December 1995, a preliminary conceptual design for the fuel cell installation was prepared. Figure 3 shows the layout of the hospital mechanical/electrical rooms, an outdoor equipment yard and an open space area between them.

The fuel cell was originally proposed to be located adjacent to the outdoor equipment yard that contained cooling towers, an electrical room, and three 1,000 kW backup generators. Because the open space between the equipment yard and the hospital building had a 5 to 10 percent grade, locating the fuel cell next to the mechanical rooms was deemed problematic. Subsequently, aesthetic and practical issues were resolved and the fuel cell was sited next to the mechanical rooms. This new location provided closer proximity to both the natural gas and thermal interface locations.

The main natural gas line enters the building just outside the boiler room. The gas line would to be tapped into and run over the to fuel cell pad (approximately 50 ft).

The fuel cell electrical interface was originally to be tied into the low voltage side of the 12,000/480V transformers located in the equipment yard. Once the fuel cell location was moved, the point of electrical interface was moved to the electrical panels located inside the hospital building. A dedicated load would later be identified for connecting to the grid-independent output interface of the fuel cell.

The thermal interface was to tie into the domestic hot water (DHW) system at the hospital. Figure 4 shows the proposed fuel cell thermal interface where water is pulled from the make-up line, heated up in the fuel cell, and then sent back to the DHW steam heaters. The tank size was reduced to 1,000 gal for the actual installation. The thermal piping distance was estimated at approximately 35 ft.

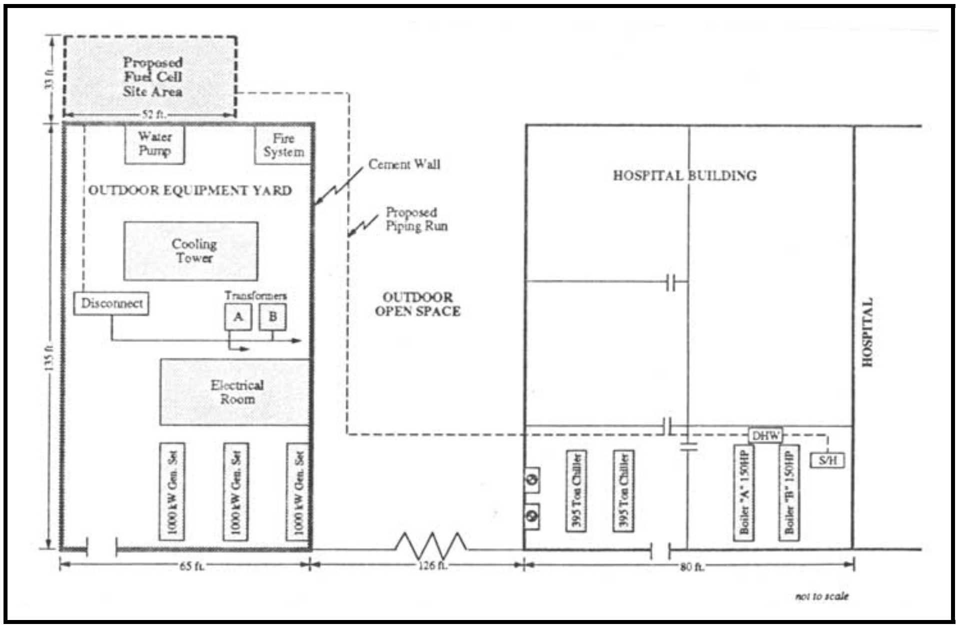


Figure 3. Original conceptual fuel cell location and interfaces (later changed).

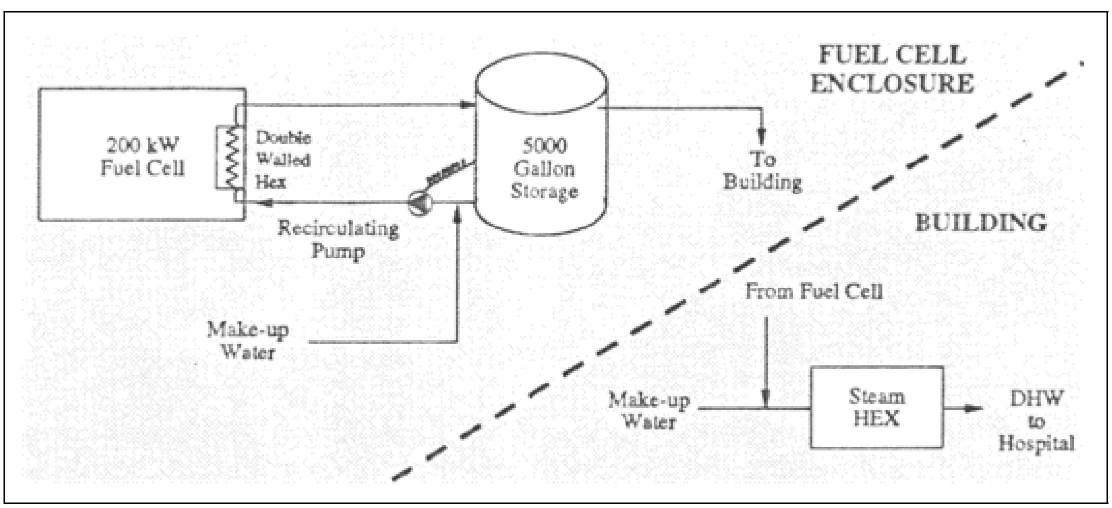


Figure 4. Original conceptual fuel cell thermal interface.

3.3 Detailed Design Drawings

UTC Fuel Cells submitted an original set of design drawings on 16 January 1995. The drawings were reviewed by base personnel, ERDC-CERL and SAIC. New drawings were made for the design review meeting held on 2 March 1995 at the Naval Hospital. Appendix B includes the attendees list.

The following drawings were submitted:

- **S-1:** Foundation Layout Plan
- **S-2:** Foundation Layout Plan / Side View A-A
- **ME-1:** Site Layout Plan with Mechanical & Electrical Routing
- **M-1**: Heat Recovery Piping & Instrumentation
- **M-2:** Mechanical Piping Details
- **E-1:** Electrical Wiring Diagram
- **E-2:** Electrical Interface Details
- **E-3:** Electrical Details

The most significant changes from the initial conceptual design involved moving the fuel cell from the equipment yard to a location with closer proximity to the mechanical building, reducing the size of the storage tank from 5,000 to 1,000 gal and adding a grid-independent interface with the hospital.

Reviewers submitted comments based on the initial drawings. Appendix C includes copies of these comments. Table 3 lists the changes made to the detailed site drawings, both before and after the design review meeting. Figures 5 through 12 show the final installation drawings.

Table 3. List of changes to design drawings based on comments.

Drawing	Changes
S-1	1. Equipment positioning adjustments made including nitrogen tank rack to back side of pad.
	2. Fence lengthened 1 ft. to 52 ft.
	3. Full concrete pad within fence.
	4. Add drainage accommodations at building end of pad.
S-2	1. Equipment position adjustments.
ME-1	1. DHW interface piping size changed from 2” to 3.”
	2. Rerouted high pressure gas line up to fuel cell pad where low pressure regulator would be installed.
	3. Phone line conduit added to drawing.
	4. Typographical error corrected: gas pipe is 3,” not 3’.
	5. Equipment position adjustments as on S-1.
	6. Spare conduit added (emergency power cord).
	7. Building wall penetrations noted.

Drawing	Changes
	8. Disconnect labels changed (reversed GC & GI).
M-1	1. Noted added that contractor would inspect water make-up line to insure that potable water system is isolated from city water system by an approved backflow prevention device in the existing system.
	2. Typographical error corrected: water tank diameter 4 ft, not 4 in.
	3. Mixing valves labeled.
	4. Closed valves illustrated
M-2	No changes.
E-1	1. Grounding illustration changed to correspond to E-3 drawing.
E-2	No Changes
E-3	1. Ground grid updated.

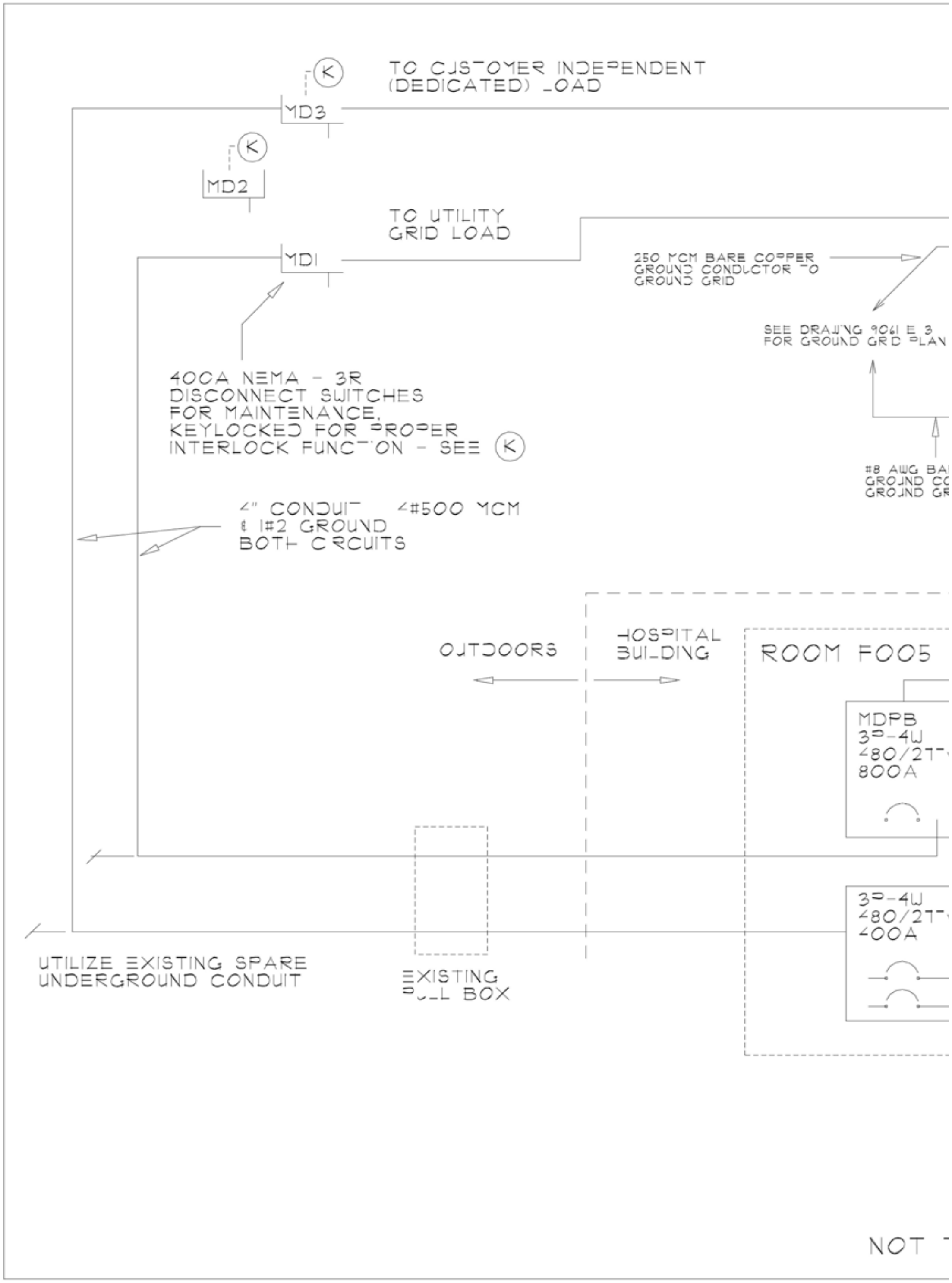
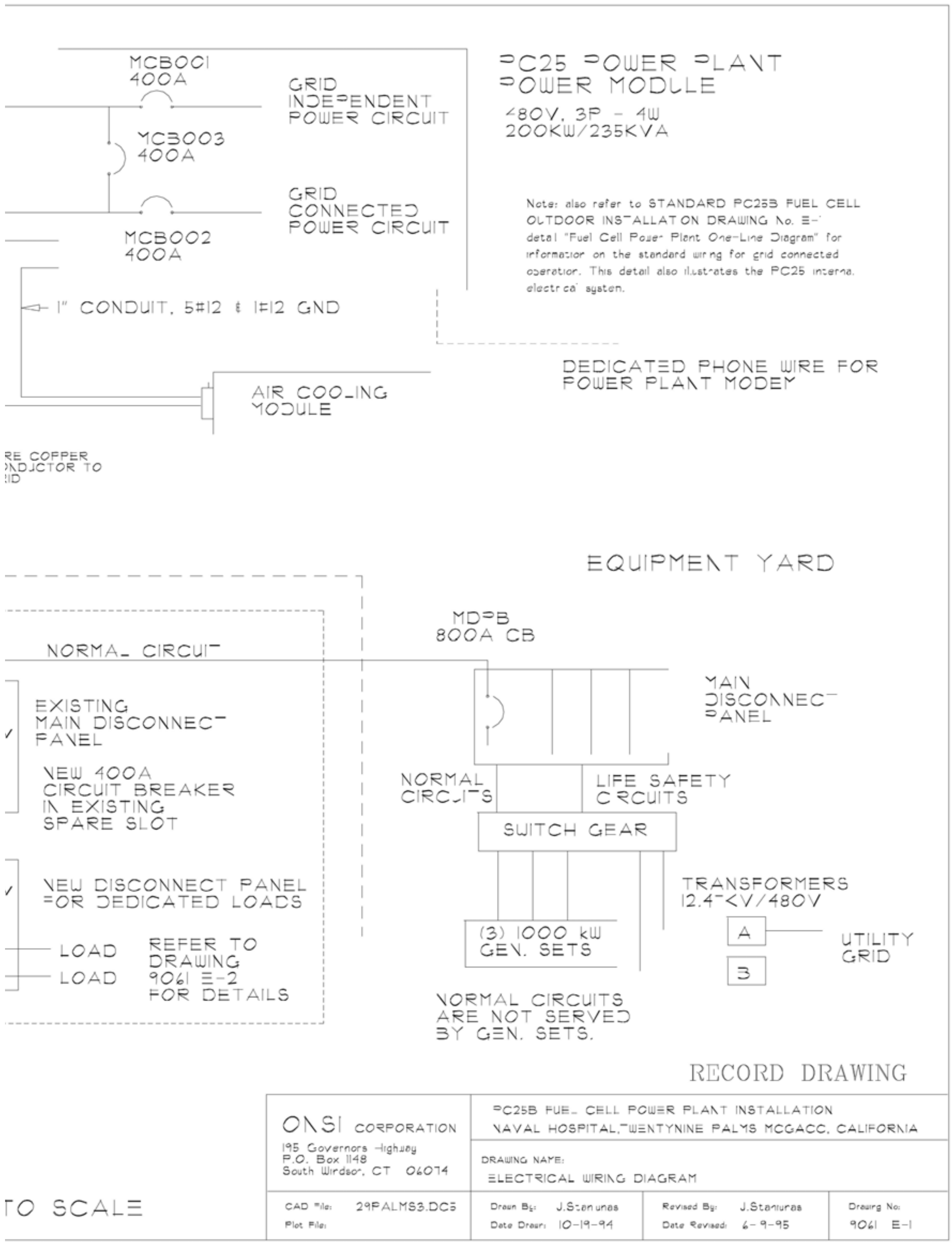
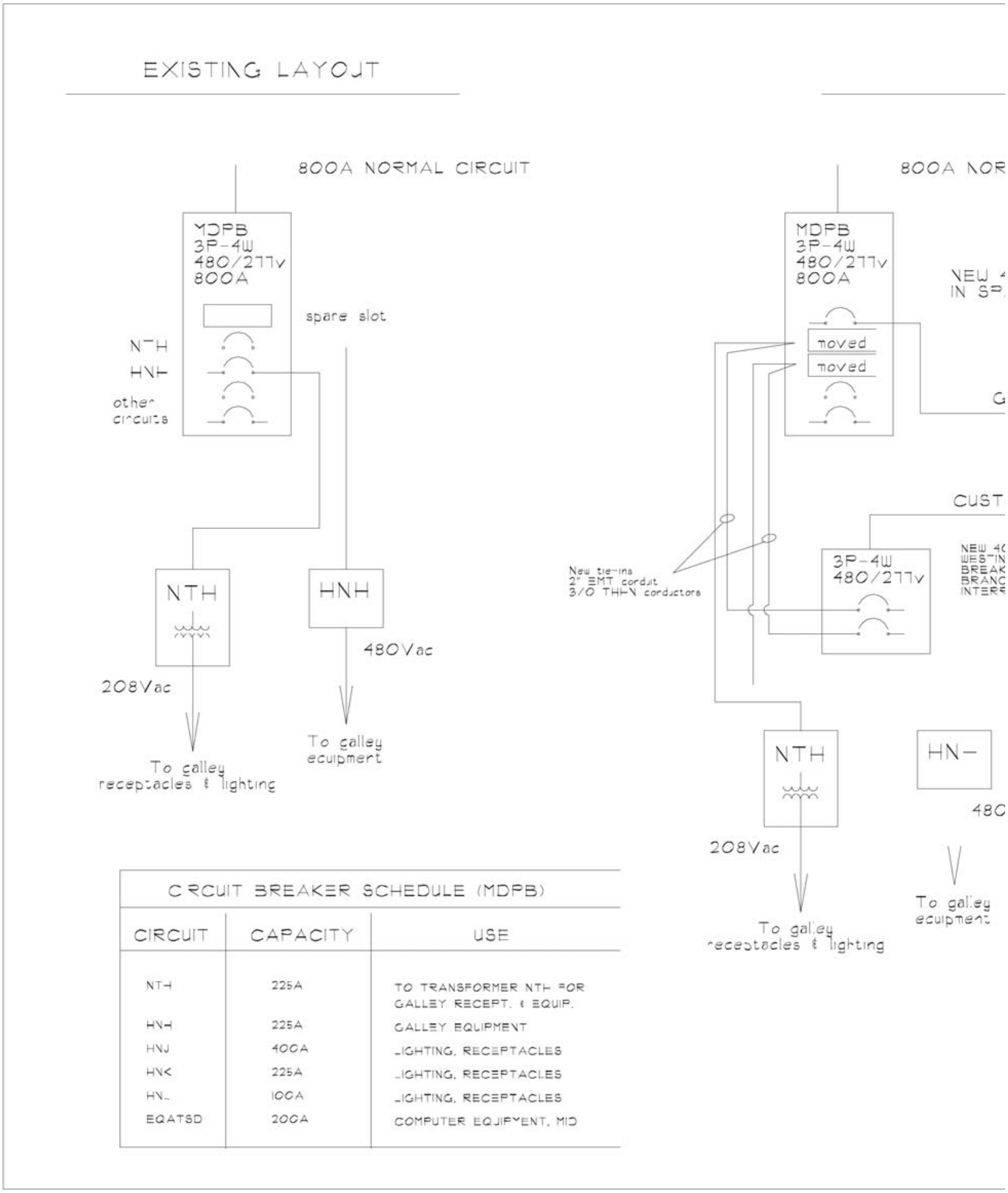


Figure 5. Final installation drawing – electrical wiring diagram.



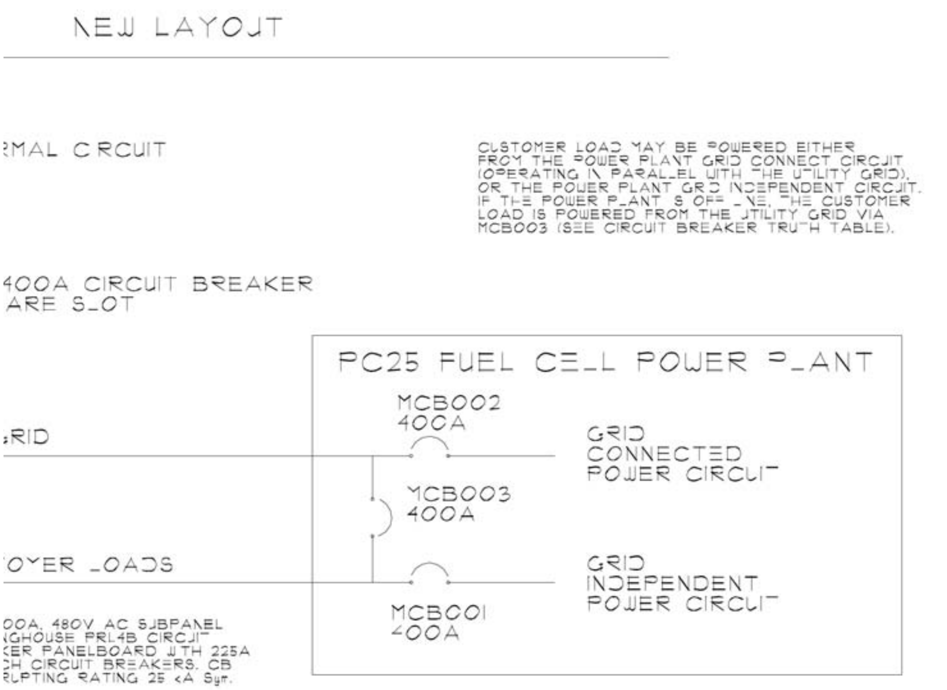
PC25 POWER PLANT
POWER MODULE
480V, 3P - 4W
200KW/235KVA
MCB001
400A
MCB003
400A
MCB002
400A
GRID INDEPENDENT POWER CIRCUIT
GRID CONNECTED POWER CIRCUIT
Note: also refer to STANDARD PC25B FUEL CELL OUTDOOR INSTALLATION DRAWING No. E-1 detail "Fuel Cell Power Plant One-Line Diagram" for information on the standard wiring for grid connected operation. This detail also illustrates the PC25 internal electrical system.
1" CONDUIT, 5#12 & 1#12 GND
DEDICATED PHONE WIRE FOR POWER PLANT MODEM
AIR COOLING MODULE
EQUIPMENT YARD
NORMAL CIRCUIT
MDPB
800A CB
MAIN DISCONNECT PANEL
EXISTING MAIN DISCONNECT PANEL
NEW 400A CIRCUIT BREAKER IN EXISTING SPARE SLOT
NORMAL CIRCUITS
LIFE SAFETY CIRCUITS
SWITCH GEAR
NEW DISCONNECT PANEL FOR DEDICATED LOADS
TRANSFORMERS
12.47KV/480V
A
B
UTILITY GRID
LOAD
LOAD
REFER TO DRAWING 9061 E-2 FOR DETAILS
(3) 1000 kW GEN. SETS
NORMAL CIRCUITS ARE NOT SERVED BY GEN. SETS.
TO SCALE
RECORD DRAWING
ONSI CORPORATION
195 Governors Highway
P.O. Box 1148
South Windsor, CT 06074
PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA
DRAWING NAME:
ELECTRICAL WIRING DIAGRAM
CAD File: 29PALMS3.DC5
Plot File:
Drawn By: J.Stanunas
Date Drawn: 10-19-94
Revised By: J.Stanunas
Date Revised: 6-9-95
Drawing No:
9061 E-1



CIRCUIT BREAKER SCHEDULE (MDPB)

CIRCUIT	CAPACITY	USE
NTH	225A	TO TRANSFORMER NTH FOR GALLEY RECEPT. & EQUIP.
HNH	225A	GALLEY EQUIPMENT
HNJ	400A	LIGHTING, RECEPTACLES
HNK	225A	LIGHTING, RECEPTACLES
HNL	100A	LIGHTING, RECEPTACLES
EQATSD	200A	COMPUTER EQUIPMENT, MID

Figure 6. Final installation drawing – electrical interface details.



PC25 OUTPUT CIRCUIT BREAKER TRUTH TABLE

CIRCUIT BREAKER	POWER PLANT MODE		
	OFF	GRID CONN.	GRID INDEP.
MCB001	OPEN	OPEN	CLOSED
MCB002	OPEN	CLOSED	OPEN
MCB003	CLOSED	CLOSED	OPEN

RECORD DRAWING

ONSI CORPORATION
195 Governors Highway
P.O. Box 1148
South Windsor, CT 06074

PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA

DRAWING NAME:
ELECTRICAL INTERFACE DETAILS

CAD File: 29PALMS3.DCS	Drawn By: J.Stanunas	Revised By: J.Stanunas	Drawing No:
Plot File:	Date Drawn: 10-19-94	Date Revised: 6-19-95	9061 E-2

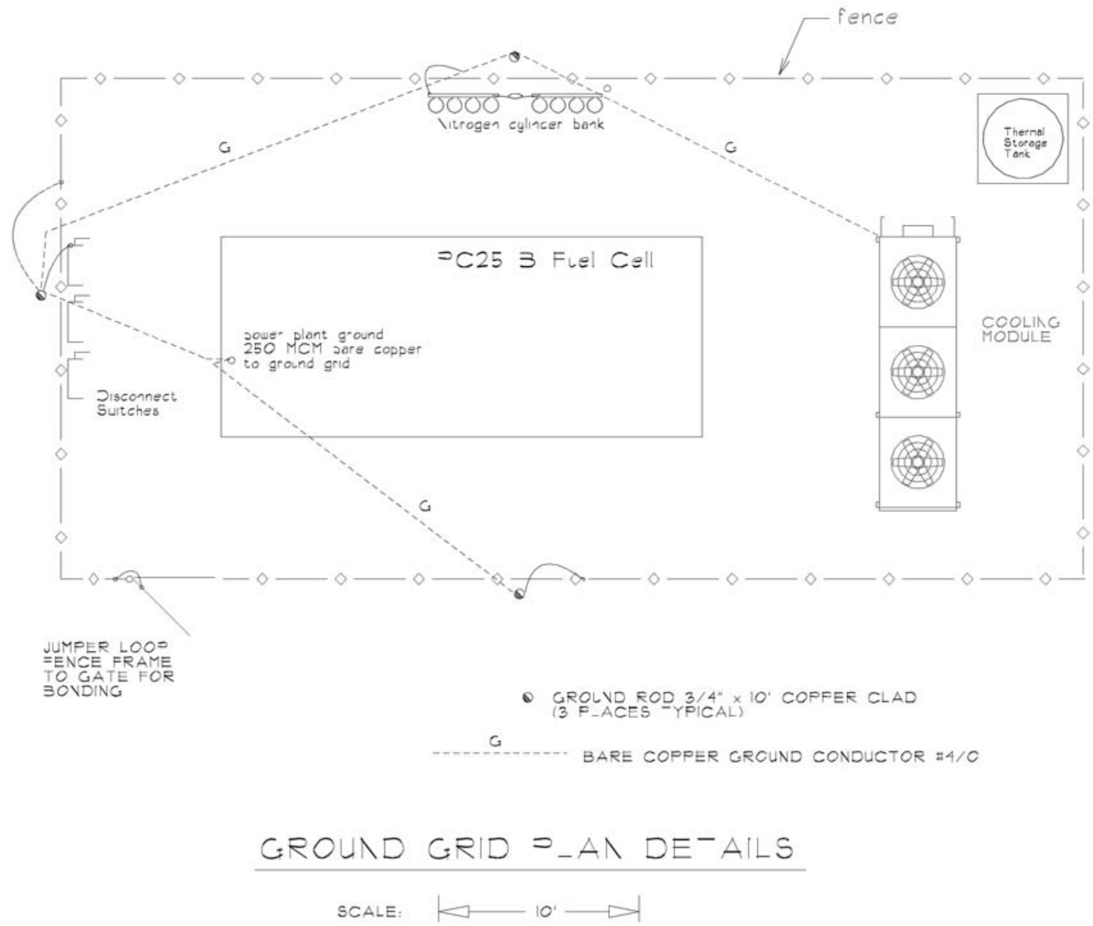
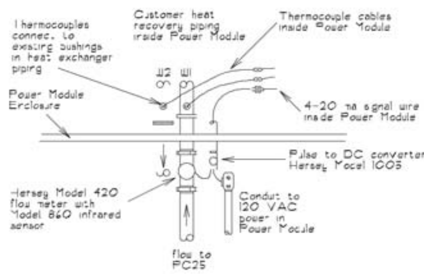
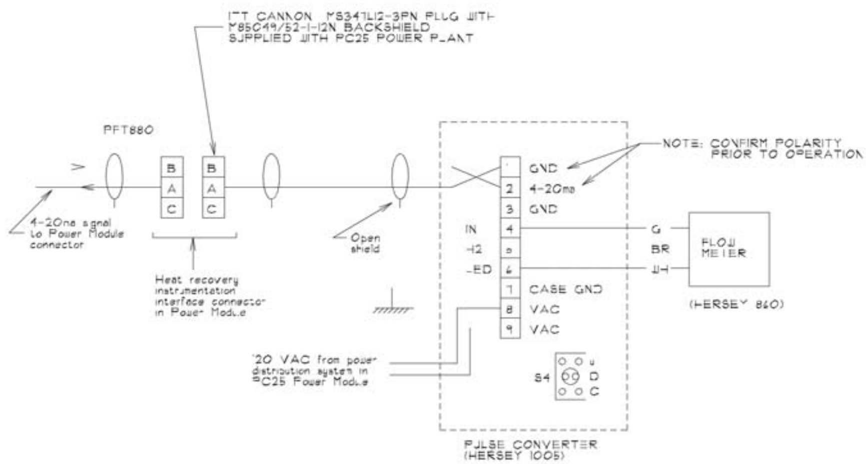


Figure 7. Final installation drawing – ground grid plan details.





POWER PLANT HEAT RECOVERY BTU METERING

(NOT TO SCALE)

RECORD DRAWING

REVISIONS
Revision No. 1
Description:
1" drain line changed to 3". Descriptions regarding the 120V supply to flowmeter and the output power to Room FC05 clarified.

ONSI CORPORATION
195 Governors Highway
P.O. Box 148
South Windsor, CT 06074

PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL,TWENTYNINE PALMS MCGACC, CALIFORNIA

DRAWING NAME:
ELECTRICAL DETAILS

CAD File:	29PALMS3.DC5	Drawn By:	J.Staniunas	Revised By:	J.Staniunas	Drawing No:
Plot File:		Date Drawn:	2-27-95	Date Revised:	6-19-95	906 E-3

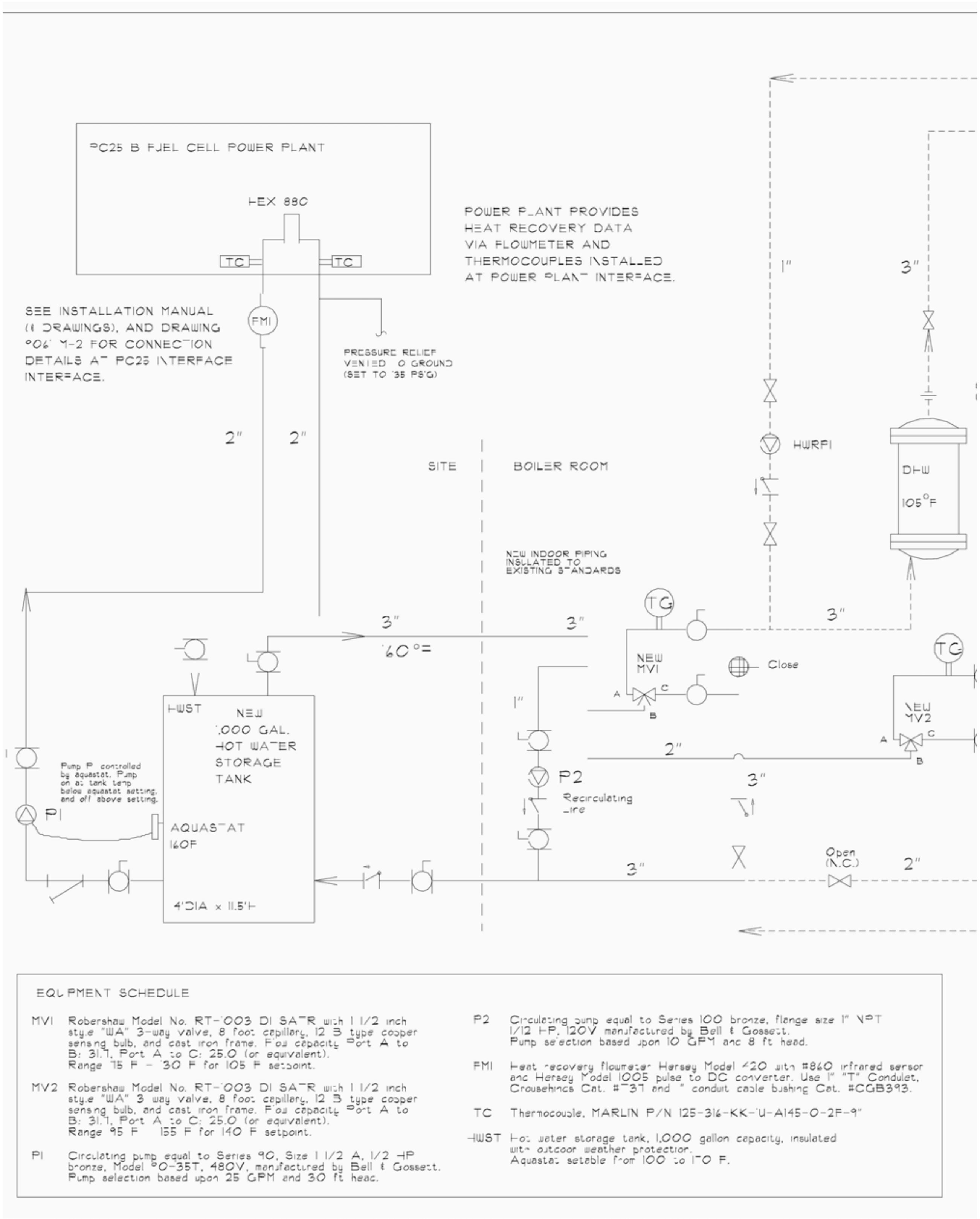
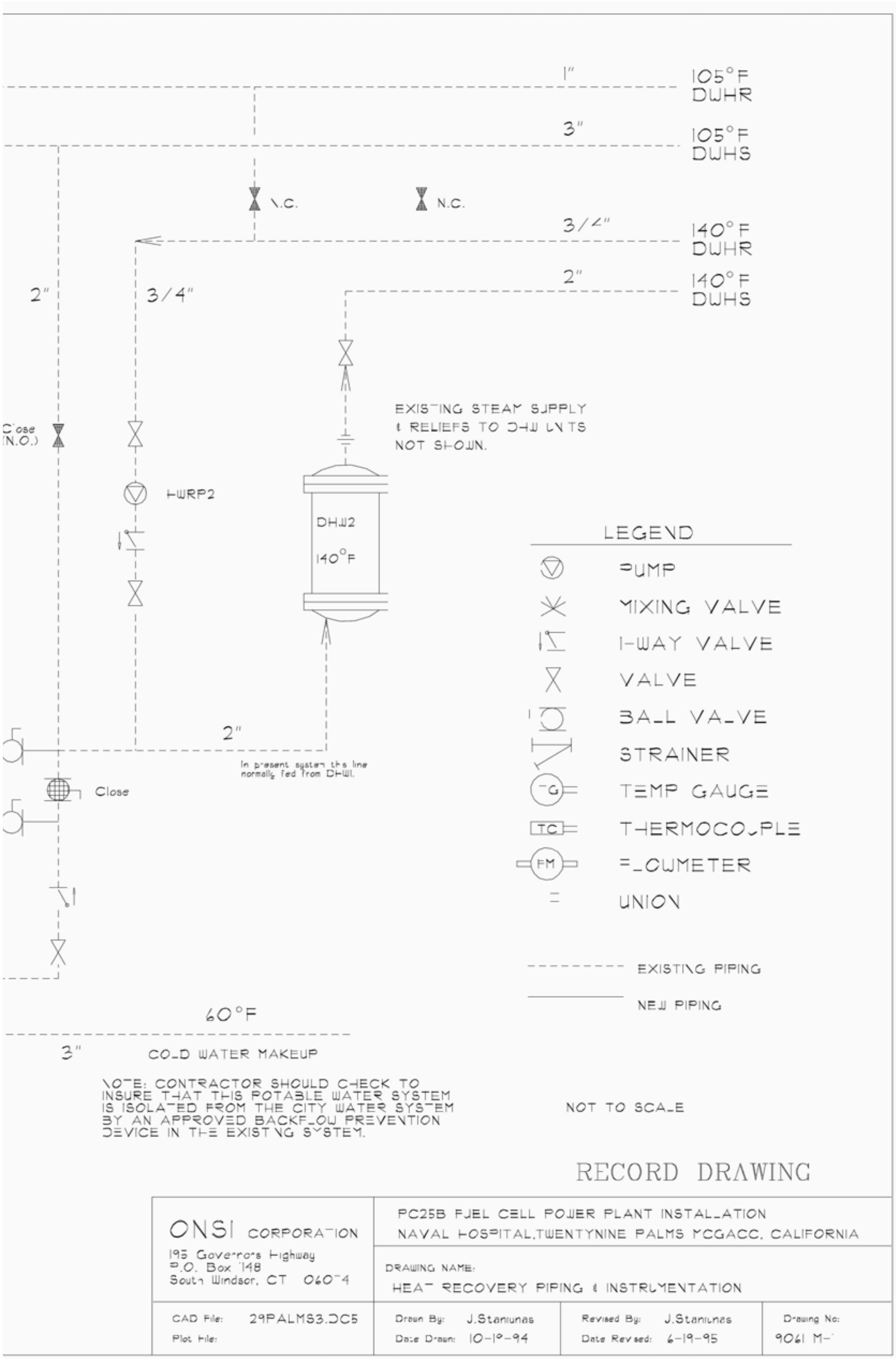


Figure 8. Final installation drawing – heat recovery piping and instrumentation.


1"
105°F DWHR
3"
105°F DWHS
N.C.
N.C.
3/4"
140°F DWHR
2"
140°F DWHS
2"
3/4"
EXISTING STEAM SUPPLY & RELIEFS TO DHW UNITS NOT SHOWN.
Close (N.O.)
HWRP2
DHW2
140°F
LEGEND
PUMP
MIXING VALVE
1-WAY VALVE
VALVE
BALL VALVE
STRAINER
TEMP GAUGE
THERMOCOUPLE
FLOWMETER
UNION
2"
In present system this line normally fed from DHW1.
Close
EXISTING PIPING
NEW PIPING
60°F
3"
COLD WATER MAKEUP
NOTE: CONTRACTOR SHOULD CHECK TO INSURE THAT THIS POTABLE WATER SYSTEM IS ISOLATED FROM THE CITY WATER SYSTEM BY AN APPROVED BACKFLOW PREVENTION DEVICE IN THE EXISTING SYSTEM.
NOT TO SCALE
RECORD DRAWING
ONSI CORPORATION
195 Governors Highway
P.O. Box 148
South Windsor, CT 06074
PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL,TWENTYNINE PALMS MCGACC, CALIFORNIA
DRAWING NAME:
HEAT RECOVERY PIPING & INSTRUMENTATION
CAD File: 29PALMS3.DC5
Plot File:
Drawn By: J.Staniunas
Date Drawn: 10-19-94
Revised By: J.Staniunas
Date Revised: 6-19-95
Drawing No:
9061 M-

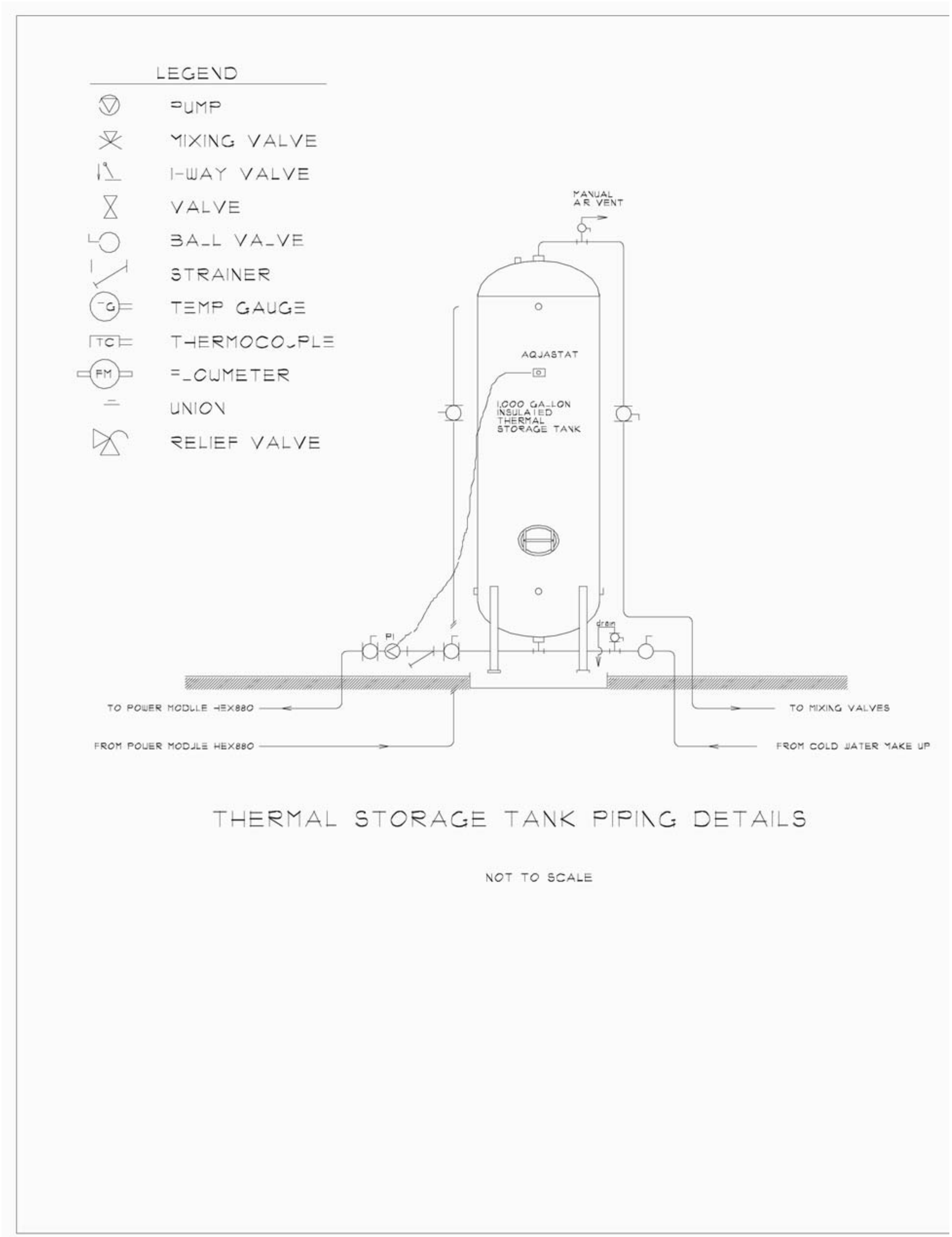
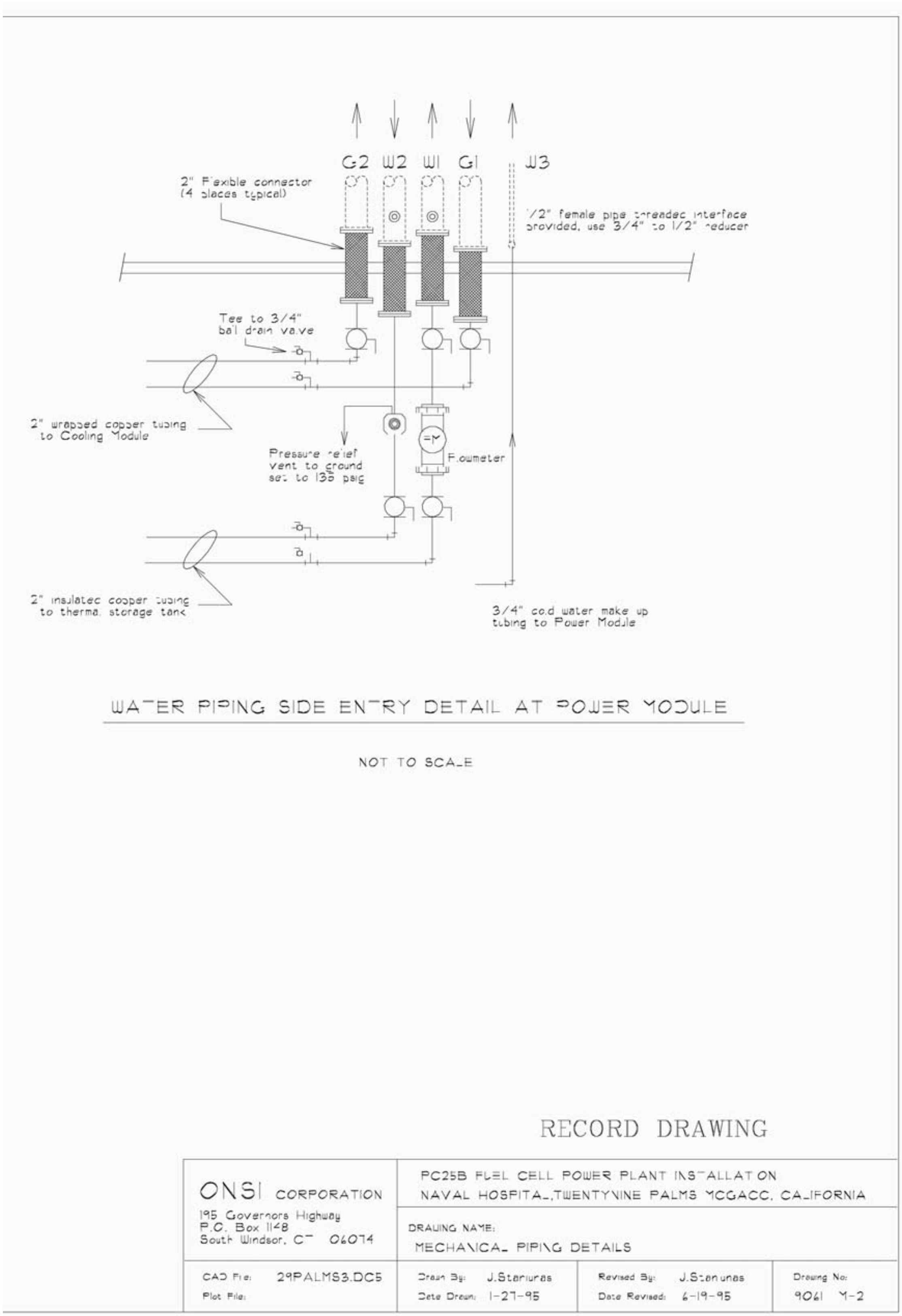


Figure 9. Final installation drawing – mechanical piping details.


G2 W2 W1 G1 W3
2" Flexible connector
(4 places typical)
1/2" female pipe threaded interface
provided, use 3/4" to 1/2" reducer
Tee to 3/4"
ball drain valve
2" wrapped copper tubing
to Cooling Module
Pressure relief
vent to ground
set to 135 psig
Flowmeter
2" insulated copper tubing
to thermal storage tank
3/4" cold water make up
tubing to Power Module
WATER PIPING SIDE ENTRY DETAIL AT POWER MODULE
NOT TO SCALE
RECORD DRAWING
ONSI CORPORATION
195 Governors Highway
P.O. Box 1148
South Windsor, CT 06074
PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA
DRAWING NAME:
MECHANICAL PIPING DETAILS
CAD File: 29PALMS3.DC5
Plot File:
Drawn By: J.Stanunas
Date Drawn: 1-27-95
Revised By: J.Stanunas
Date Revised: 6-19-95
Drawing No: 9061 M-2

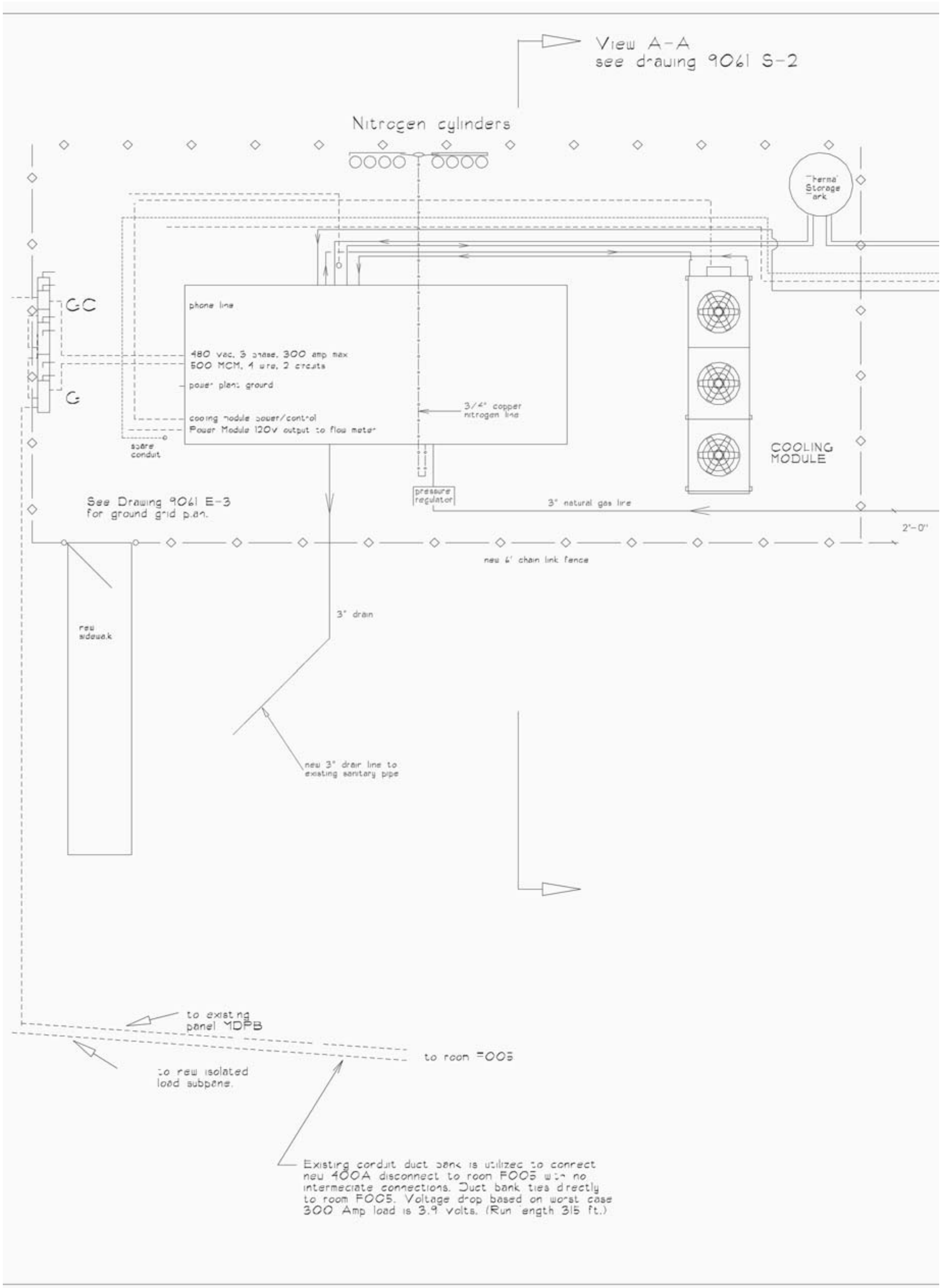
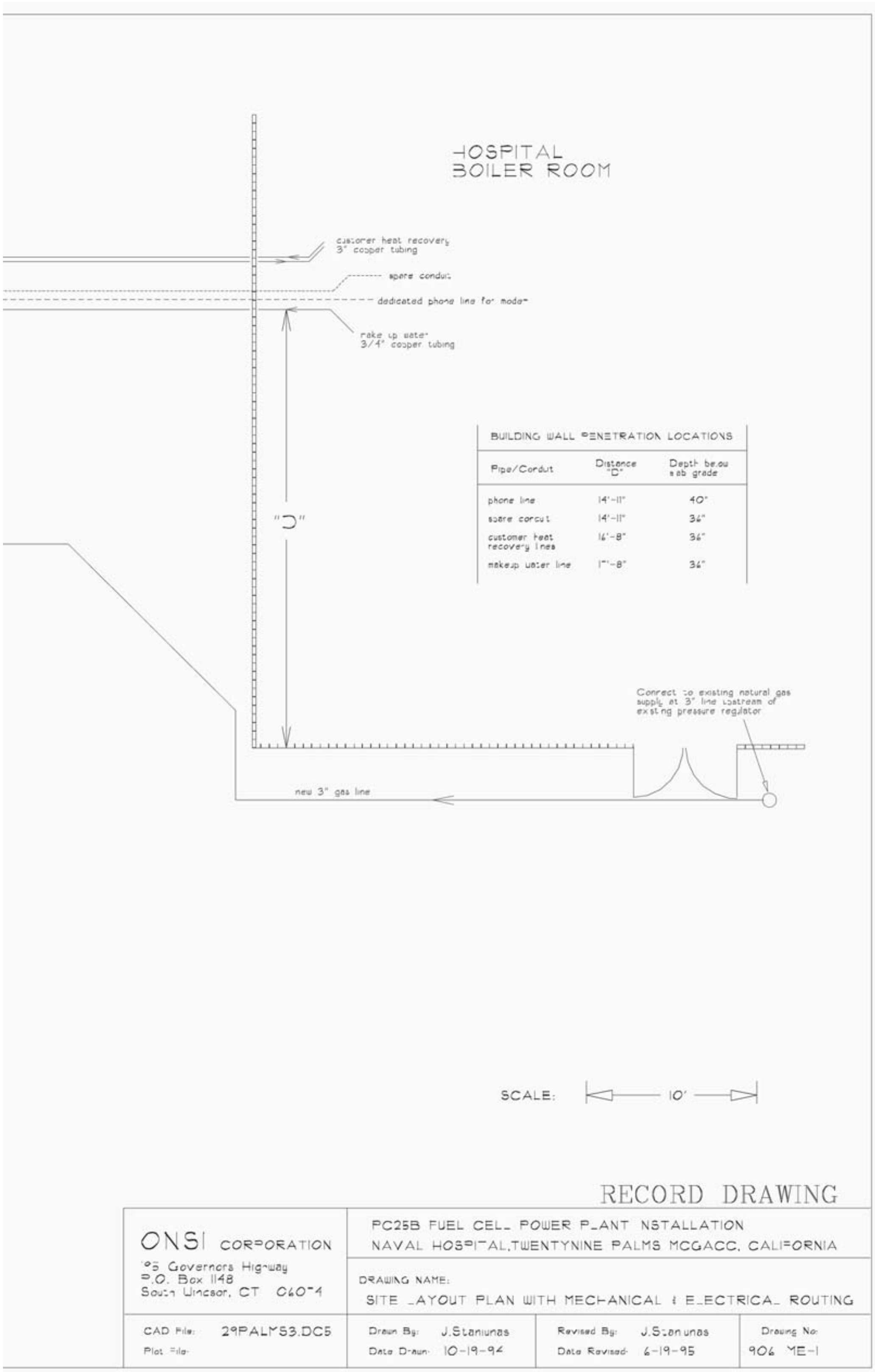


Figure 10. Final installation drawing – layout plan with mechanical and electrical routing.


HOSPITAL
BOILER ROOM
customer heat recovery 3" copper tubing
spare conduit
dedicated phone line for modem
make up water 3/4" copper tubing
"D"
BUILDING WALL PENETRATION LOCATIONS
Pipe/Conduit
Distance "D"
Depth below slab grade
phone line 14'-11" 40"
spare conduit 14'-11" 36"
customer heat recovery lines 16'-8" 36"
makeup water line 36"
Connect to existing natural gas supply at 3" line upstream of existing pressure regulator
new 3" gas line
SCALE: 10'
RECORD DRAWING
ONSI CORPORATION
95 Governors Highway
P.O. Box 1148
South Windsor, CT 06074
PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA
DRAWING NAME:
SITE LAYOUT PLAN WITH MECHANICAL & ELECTRICAL ROUTING
CAD File: 29PALMS3.DC5
Plot File:
Drawn By: J.Staniunas
Date Drawn: 10-19-94
Revised By: J.Staniunas
Date Revised: 6-19-95
Drawing No: 906 ME-1

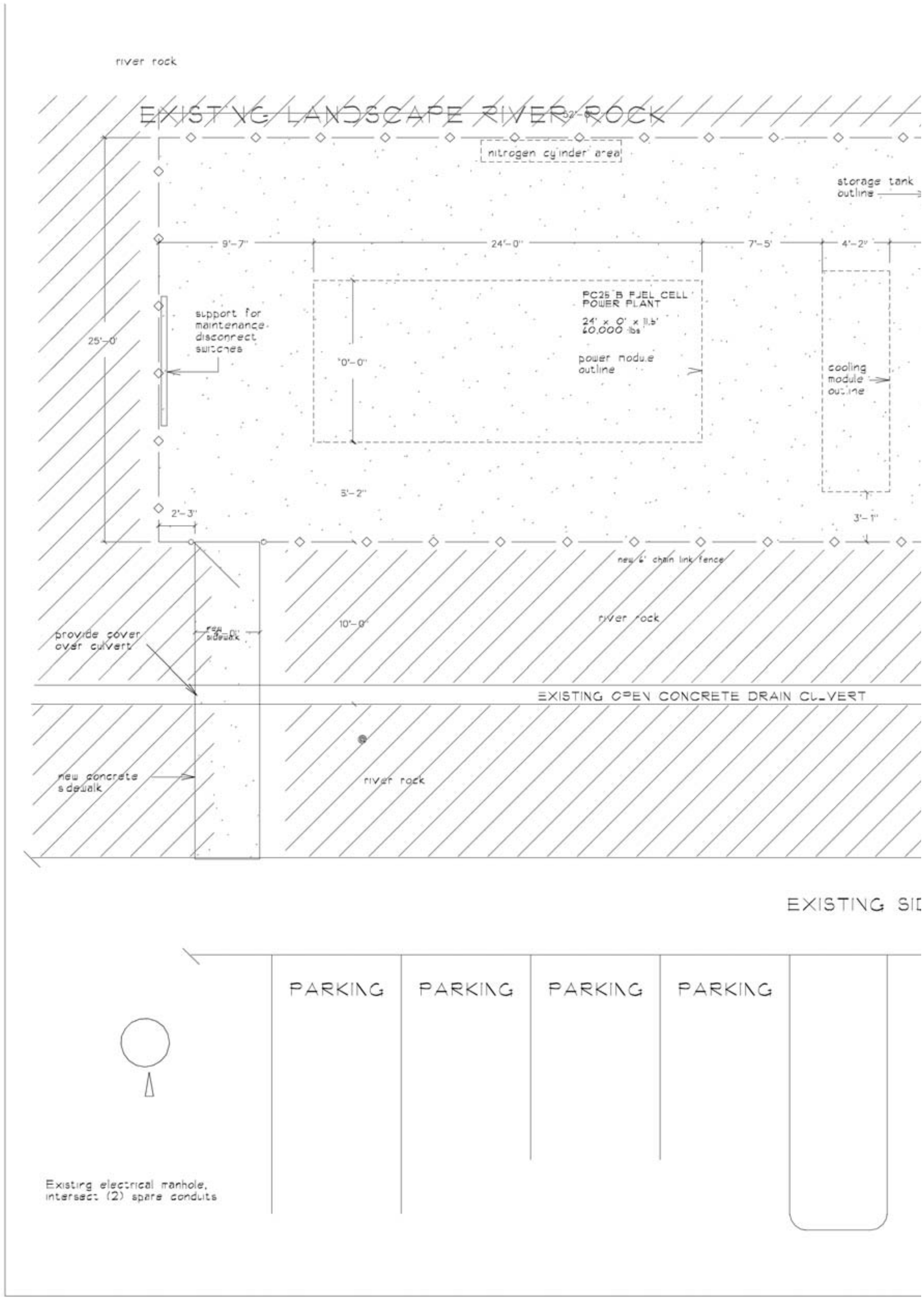
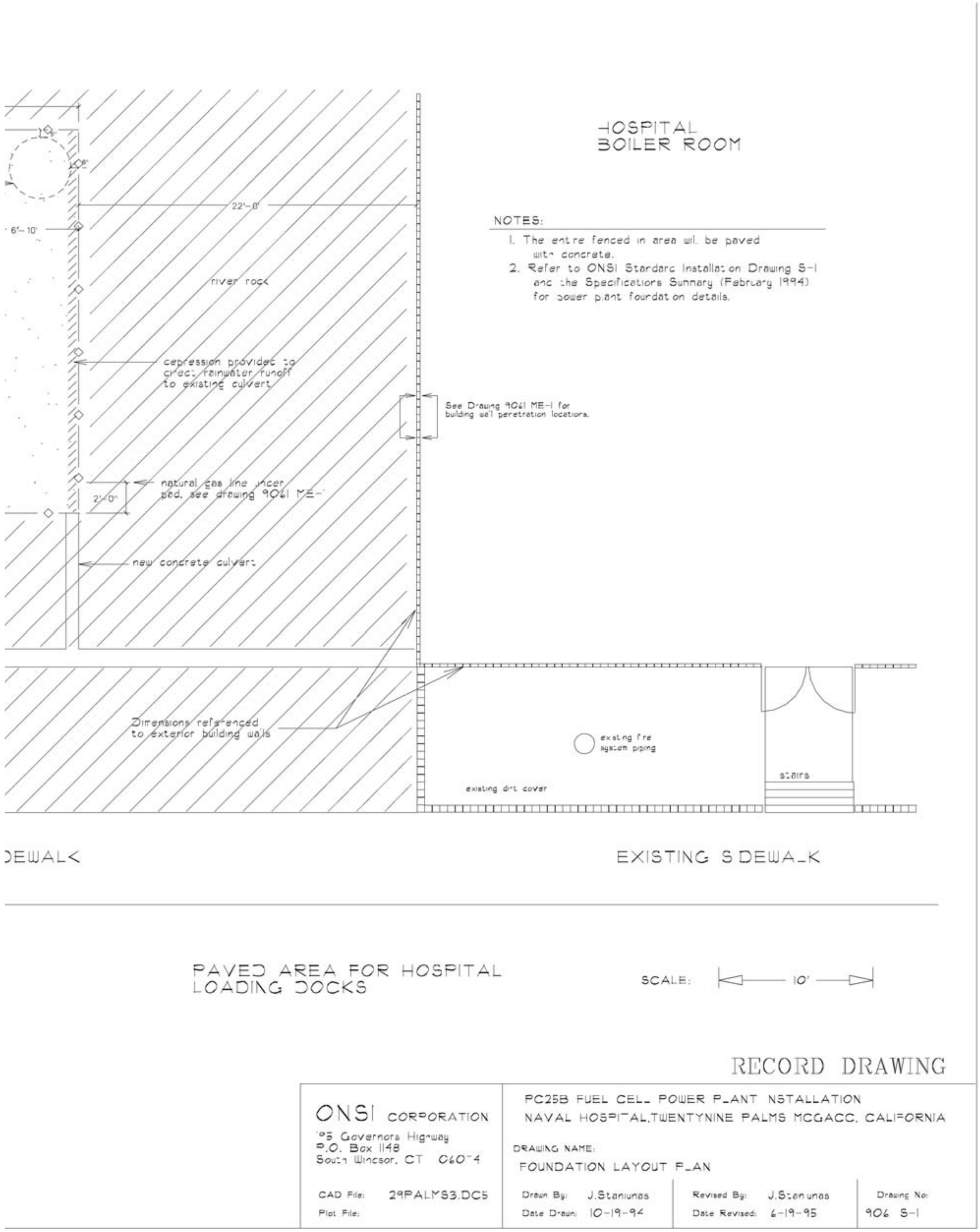


Figure 11. Final installation drawing – foundation layout plan.


HOSPITAL
BOILER ROOM
NOTES:
1. The entire fenced in area will be paved with concrete.
2. Refer to ONSI Standard Installation Drawing S-1 and the Specifications Summary (February 1994) for power plant foundation details.
22'-0"
6'-10"
river rock
depression provided to direct rainwater runoff to existing culvert
See Drawing 9061 ME-1 for building wall penetration locations.
natural gas line under pad, see drawing 9061 ME-
2'-0"
new concrete culvert
Dimensions referenced to exterior building walls
existing fire system piping
stairs
existing dirt cover
DEWALK
EXISTING SIDEWALK
PAVED AREA FOR HOSPITAL LOADING DOCKS
SCALE: 10'
RECORD DRAWING
ONSI CORPORATION
195 Governors Highway
P.O. Box 1148
South Windsor, CT 06074
PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL, TWENTYNINE PALMS MCGACC, CALIFORNIA
DRAWING NAME:
FOUNDATION LAYOUT PLAN
CAD File: 29PALMS3.DC5
Plot File:
Drawn By: J.Staniunas
Date Drawn: 10-19-94
Revised By: J.Staniunas
Date Revised: 6-19-95
Drawing No: 906 S-1

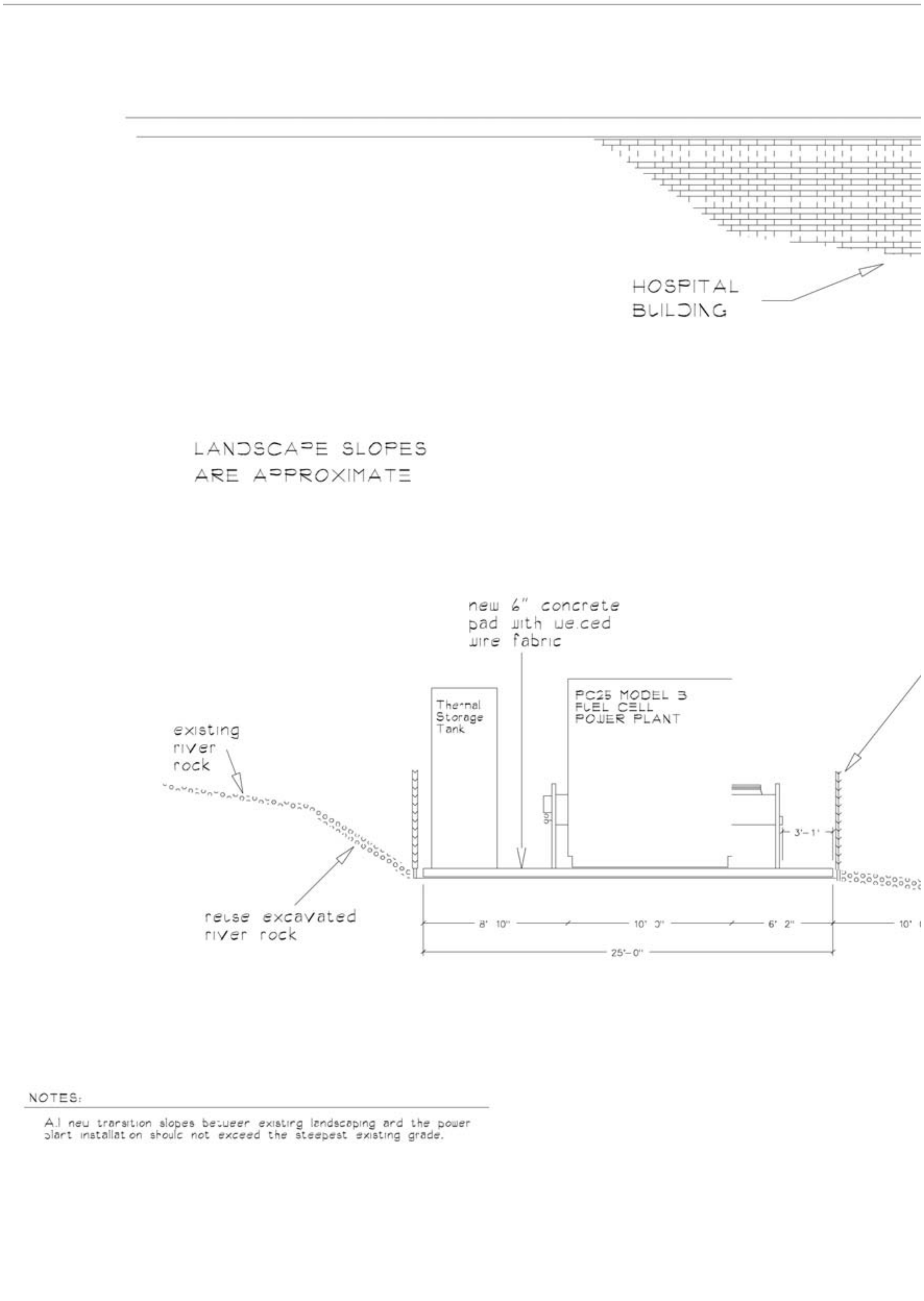
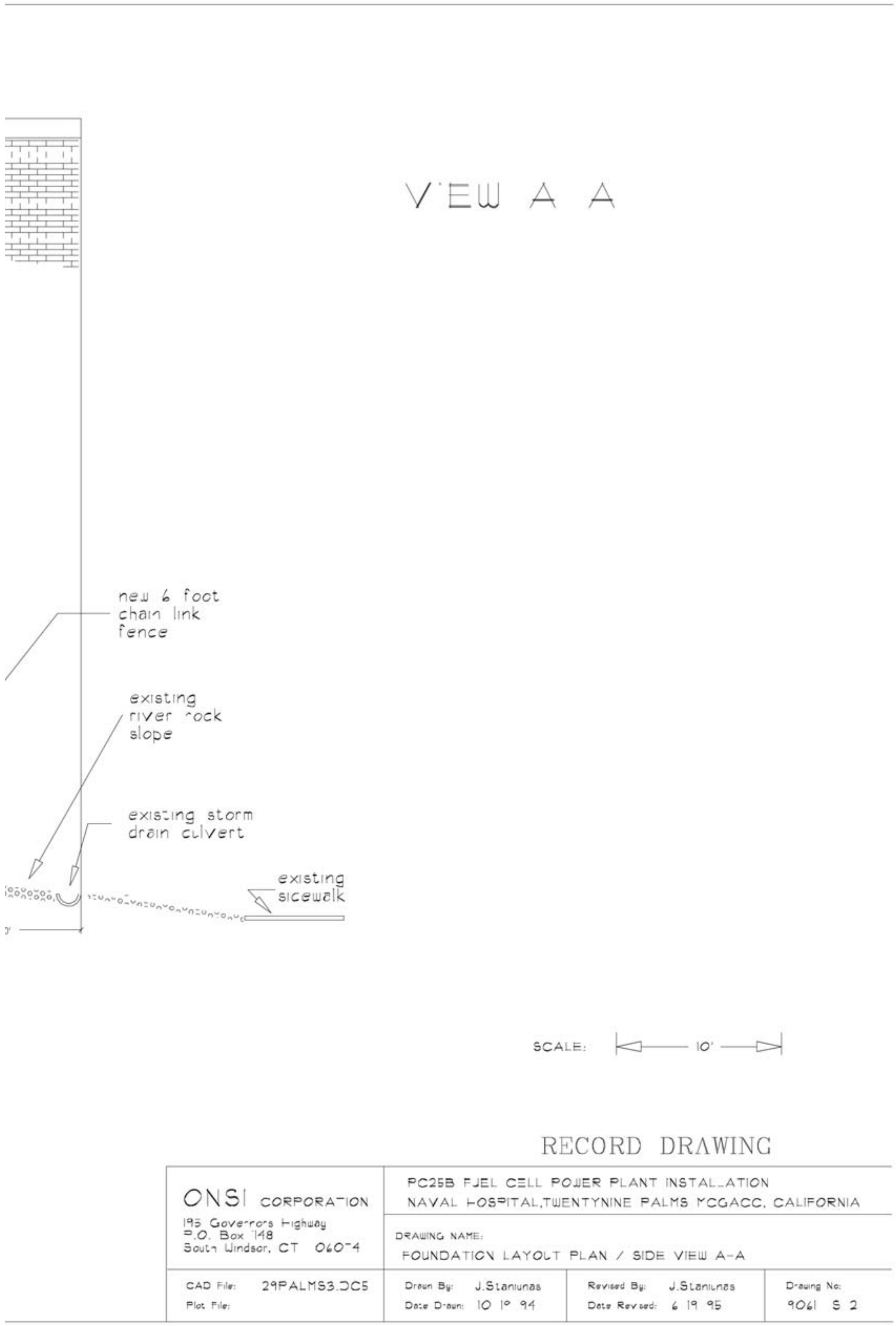


Figure 12. Final installation drawing – foundation layout plan side view.


VIEW A A
new 6 foot chain link fence
existing river rock slope
existing storm drain culvert
existing sidewalk
SCALE: 10'
RECORD DRAWING
ONSI CORPORATION
195 Governors Highway
P.O. Box 148
South Windsor, CT 06074
PC25B FUEL CELL POWER PLANT INSTALLATION
NAVAL HOSPITAL,TWENTYNINE PALMS MCGACC, CALIFORNIA
DRAWING NAME:
FOUNDATION LAYOUT PLAN / SIDE VIEW A-A
CAD File: 29PALMS3.DC5
Plot File:
Drawn By: J.Staniunas
Date Drawn: 10 19 94
Revised By: J.Staniunas
Date Revised: 6 19 95
Drawing No: 9061 S 2

4 Fuel Cell Performance

This Chapter summarizes fuel cell operating performance, outage history, and maintenance activities.

4.1 Operating History

The fuel cell started operation in mid-June of 1995. Acceptance tests were performed between 16 and 21 June. Appendix A includes the Acceptance Test Report. Official data recording for the demonstration began on 20 June. The formal acceptance test meeting was held a few days later on 23 June, with title to the fuel cell transferred to the Naval Hospital using Form DD250. The power plant continued to operate (for 912 hours of continuous operation) until an event on 28 July 1995. A total of 36 power plant shut downs were recorded between 20 June 1995 with the final shut down occurring on 26 May 2000. There were 33 forced outages and 3 scheduled outages.

Performance data was collected via UTC Fuel Cells' RADAR data acquisition system. Using a modem and telephone line, the power plant was called routinely to retrieve a "snapshot" of the current status. Included in the metrics collected were cumulative totals for hot time, load time, MWHrs, input fuel, thermal output, etc. These data records were then used to generate the various performance parameters discussed in this report.

A total of 21,890 operating load hours were recorded for the Naval Hospital fuel cell. Of the 36 separate operating periods, eight of them had continuous fuel cell operating hours of more than 1,000 hours. The longest continuous operating period was 2,069 hours (~12 weeks) and occurred between 9 August and 3 November 1996. Table 4 lists the distribution of continuous periods of operation for this fuel cell.

Figure 13 shows the hours of operation and outages on a monthly basis for the entire demonstration period. Between 20 June 1995 and 20 May 2000 (43,094 hours), the fuel cell operated a total of 21,890 hours, which represents an availability of 50.8 percent.

Table 4. Distribution of continuous hours of operation.

Hours of Operation	Occurrences
Over 3,000 hours	0
2,001 – 3,000 hours	1
1,001 – 2,000 hours	7
751 – 1,000 hours	5
501 – 750 hours	5
250 – 500 hours	4
Less than 250 hours	14

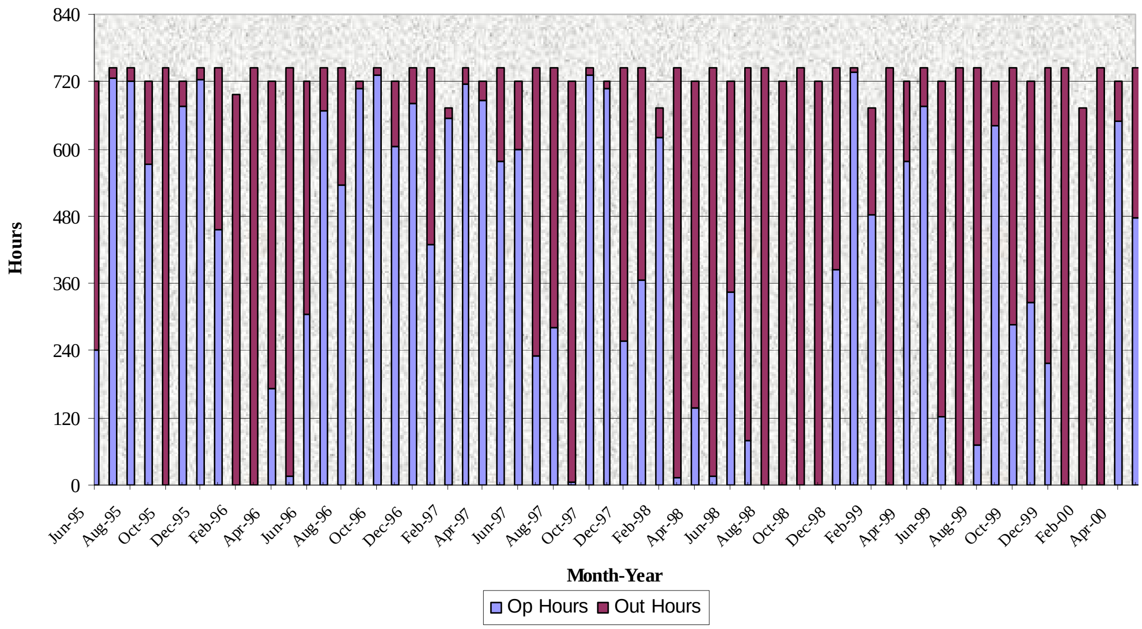


Figure 13. Fuel cell operating hours by month.

The fuel cell generated over 3.5 million kWh of electricity for the Naval Hospital during the demonstration period. The data listed in Table 5 summarize annual fuel cell electrical performance at the Naval Hospital. The average electrical output of the fuel cell during operation was 161 kW over the 5+ year period. The data shows that the average annual rate of electrical output from the fuel cell through 1997 was 175 kW and decreased to an average low of 123 kW in 1999.

Table 5. Fuel cell electrical performance characteristics.

Year	Operating Hours	MWhrs	Avg. kW
1995	3,705	633.8	171
1996	4,836	838.8	173
1997	5,970	1,071.5	179
1998	1,989	315.8	159
1999	4,253	521.7	123
2000	1,136	140.8	124
Total/Avg.	21,890	3,522.4	161

The average rate of heat recovered and used by the Naval Hospital "thermal utilization" was only a fraction of the fuel cell's 700,000 Btu/hour capacity. The site only used an average of 40,750 Btu/hour (<6 percent utilization). The data indicates that no heat was recovered in 2000. The level of heat recovery is important in that heat recovered from the fuel cell offsets the quantity of heat that must be produced (i.e., reduces natural gas consumption) by conventional heating systems at the facility thereby creating additional cost savings attributable to the fuel cell. Table 6 lists thermal output performance as well as natural gas consumption characteristics for the fuel cell. The fuel cell consumed natural gas at an average rate of 1,664.3 cu ft per hour during the course of the demonstration. The rate of natural gas consumption is fairly linear with the electric output at 10.5 cu ft/kW. The thermal efficiency component for the heat recovered from the fuel cell added approximately 2.38 percent to overall efficiency of the fuel cell.

Table 6. Fuel cell input fuel and thermal output characteristics.

Year	Input Fuel (cu ft)	Input Fuel (cu ft/hr)	Thermal Heat Recovery (therms)	Avg. Rate of Thermal Heat Recovery (kBtu/hr.)	Fuel Cell Thermal Efficiency (HHV) %*
1995	6,488,973.3	1,751.3	2,146.4	57.9	3.21
1996	8,339,251.1	1,724.3	3,118.1	64.5	3.63
1997	11,093,926.4	1,858.2	3,251.1	54.5	2.85
1998	3,419,098.2	1,718.7	226.2	11.2	0.63
1999	5,577,173.3	1,311.3	182.1	4.3	0.32
2000	1,514,140.0	1,333.1	0	0	0.00
Total/Avg.	36,432,562.3	1,664.3	8,923.9	40.8	2.38

* Higher Heating Value (HHV) is based on a natural gas heating value of 1,030 Btu/cubic foot.

Table 7 lists the fuel cell electrical efficiency based on higher heating value (HHV) for each year of operation. The average electrical efficiency for the demonstration was 32.0 percent (HHV).

Table 7. Fuel cell electric efficiency.

Year	MWhrs	Input Fuel (cu ft)	Electrical Efficiency (HHV)- %*
1995	633.8	6,488,973.3	32.4
1996	838.8	8,339,251.1	33.3
1997	1,071.5	11,093,926.4	32.0
1998	315.8	3,419,098.2	30.6
1999	521.7	5,577,173.3	31.0
2000	140.8	1,514,140.0	30.8
Total/Avg.	3,522.4	36,432,562.3	32.0

* Higher Heating Value (HHV) is based on a natural gas heating value of 1,030 Btu/cubic foot, calculated as:

Efficiency = ((MWhrs x 1,000,000 Watt-hrs/MWhrs x 3.413 Btu/Watt) / (cu ft x 1,030 Btu/cubic foot)) x 100

4.2 Fuel Cell Outage Summary

Between 20 June 1995 and 20 May 2000 (43,094 hours), the fuel cell had 36 outages resulting in 21,204 hours of downtime. The fuel cell's availability was 50.8 percent:

$$50.8\% = ((43{,}094 - 21{,}204) / (43{,}094)) \times 100$$

The outages were identified from the RADAR performance monitoring system data. Because data records are collected on average once per day, outage times occasionally had to be interpolated. Sometimes the modem did not respond or the phone line was down, which prevented a full complement of data records.

The longest outage was for 3,937 hours and occurred between 4 July and 15 December 1998. The next longest outage period occurred between 10 December 1999 and 3 April 2000 (2,746 hours). Table 8 lists the distribution of outage periods by hours of outage duration.

Table 9 lists the start and end dates/times (chronologically), the outage duration hours, and the outage type for the 36 individual events. Appendix D includes the complete list of outage codes for the PC25B fuel cell.

Table 8. Distribution of non-operational hours by duration.

Outage Hours	Occurrences
Over 3,000 hrs	1
2,001 – 3,000 hrs	2
1,001 – 2,000 hrs	1
751 – 1,000 hrs	1
501 – 750 hrs	0
250 – 500 hrs	10
Less than 250 hrs	27

Table 9. List of fuel cell outage periods.

No.	Off Date Stamp	On Date Stamp	Total Outage Hrs	Hours to Next Outage	Type	System	Part
		6/20/95 15:51		912.00			
1	7/28/95 15:51	7/28/95 16:24	0.55	823.10	F	APS	FT140
2	8/31/95 23:30	9/3/95 11:34	60.07	597.35	F	TMS	TCV400
3	9/28/95 08:55	11/2/95 09:11	840.27	1753.15	F	TMS	PMP400
4	1/14/96 10:20	4/17/96 14:02	2,259.70	173.85	F	OTR	SBSTK
5	4/24/96 19:53	5/4/96 18:40	238.78	15.55	F	CVS	CV500
6	5/5/96 10:13	6/14/96 13:20	963.12	5.00	F	ES	MCB001
7	6/14/96 18:20	6/18/96 22:55	100.58	968.08	F	ES	MCB002
8	7/29/96 07:00	8/9/96 15:30	272.50	2068.70	N		
9	11/3/96 20:12	11/6/96 10:19	62.12	693.02	F	TMS	FS400
10	12/5/96 07:20	12/7/96 10:50	51.50	947.87	F	OTR	
11	1/15/97 22:42	1/28/97 20:30	309.80	247.67	F	OTR	CRB
12	2/8/97 04:10	2/8/97 17:55	13.75	723.98	F	OTR	CRB
13	3/10/97 21:54	3/11/97 18:05	20.18	531.25	F	OTR	
14	4/2/97 21:20	4/3/97 20:01	22.68	1235.48	F	OTR	
15	5/25/97 07:30	6/5/97 23:25	279.92	659.68	F	FPS	
16	7/3/97 11:06	7/22/97 18:36	463.50	65.68	F	TMS	FT140
17	7/25/97 12:17	7/26/97 14:44	26.45	135.53	N		
18	8/1/97 06:16	8/13/97 16:56	298.67	120.07	F	OTR	PC
19	8/18/97 17:00	8/22/97 13:08	92.13	160.20	F	OTR	K001
20	8/29/97 05:20	9/30/97 19:28	782.13	1603.53	F	ES	UPS001
21	12/6/97 15:00	12/26/97 14:27	479.45	300.85	F	OTR	K002
22	1/8/98 03:18	1/23/98 13:50	370.53	851.75	F	OTR	FCV012
23	2/28/98 01:35	3/26/98 17:20	639.75	12.18	F	OTR	
24	3/27/98 05:31	4/18/98 11:50	534.32	137.00	F	ES	UPS001
25	4/24/98 04:50	5/11/98 19:00	422.17	17.32	F	ES	MCB003
26	5/12/98 12:19	6/16/98 16:32	844.22	429.87	F	OTR	CSA
27	7/4/98 14:24	12/15/98 16:05	3,937.68	1626.92	N	TMS	
28	2/21/99 11:00	4/6/99 21:00	1,066.00	1008.33	F	OTR	GRND

Table 9. List of fuel cell outage periods.

No.	Off Date Stamp	On Date Stamp	Total Outage Hrs	Hours to Next Outage	Type	System	Part
29	5/18/99 21:20	5/20/99 16:30	43.17	349.83	F	APS	FT140
30	6/4/99 06:20	8/20/99 13:48	1,855.47	122.18	F	OTR	
31	8/25/99 15:59	9/2/99 12:08	188.15	8.58	F	APS	FT140
32	9/2/99 20:43	9/3/99 17:12	20.48	1018.30	F	APS	FIL100
33	10/16/9903:30	11/1/99 19:31	400.02	149.02	F	WTS	
34	11/8/99 00:32	11/23/99 13:06	372.57	408.60	F	OTR	INV
35	12/10/9913:42	4/3/00 00:00	2,746.30	1134.00	F	TMS	FS400
36	5/20/00 06:00	Final Outage			F	PSS	VT310

Thirty-three of the outages were classified as "forced outages," which contributed to a total of 16,420 hours of down time. Forced outages are broadly classified by the major fuel cell sub-systems listed in Table 10.

Table 10. Forced outage categories.

Category	Description
PSS	Power section system
APS	Air processing system
CVS	Cabinet ventilation system
ES	Electrical system
FPS	Fuel processing system
OTR	Other
TMS	Thermal management system
WTS	Water treatment system

Table 11 lists the forced outages by major system categories.

Table 11. Forced outage statistics.

Category	Number of Occurrences	Total Outage Time	Min. Outage Time per Occurrences	Max. Outage Time per Occurrences	Avg. Outage Time per Occurrence
APS	4	252.4	0.6	188.2	63.1
CVS	1	238.8	238.8	238.8	238.8
ES	5	2,802.3	100.6	963.1	560.5
FPS	1	279.9	279.9	279.9	279.9
OTR	14	7,852.2	13.8	2,259.7	560.9
PSS*	1	0.0	–	–	–
TMS	6	4,594.4	60.1	2,746.3	765.7
WTS	1	400.0	400.0	400.0	400.0
	33	16,420			497.6
*Final outage (no time associated)					

Fourteen of the thirty-three (42 percent) forced outages were classified as Other. The most frequent number of outages in the Other category were attributed to circuit breakers (CRB). In addition, circuit breakers K001 and K002 were attributed to 571.6 hours of total outages. The longest outage in the Other category was 2,259.7 hours (between January and April 1996) due to a problem with the cell stack. This occurred early on in the demonstration with 4,174 load hours on the fuel cell. At this time the cell stack was replaced. In July 1996, an external reverse osmosis water treatment unit was installed to address hard water problems that were having adverse affects on the fuel cell operation. Similar characteristics were also observed in other fuel cells installed in the southwestern region of the country, including Camp Pendleton, Edwards AFB, Davis-Monthan AFB, and Fort Huachuca. After significant analysis by UTC Fuel Cells, it was concluded that the hard water characteristics of the water supply was contributing to restrictions and blockages in the cooling system, which subsequently caused some of the fuel cell stacks to overheat and fail. Hard water is water that contains a high level of dissolved minerals, most notably calcium and magnesium. The degree of hardness increases with increased levels of calcium and magnesium. When hard water is heated, the dissolved minerals precipitate out of solution and attaches to plumbing and heat exchangers. To control the water chemistry of these systems, water treatment systems were installed.

The fewest number of forced outages by major system type (one occurrence each) were for the cabinet ventilation, fuel processing, and power section systems. The outage associated with the power section system was the final outage, which was not resolved.

Figure 14 shows a graph of forced outage occurrences.

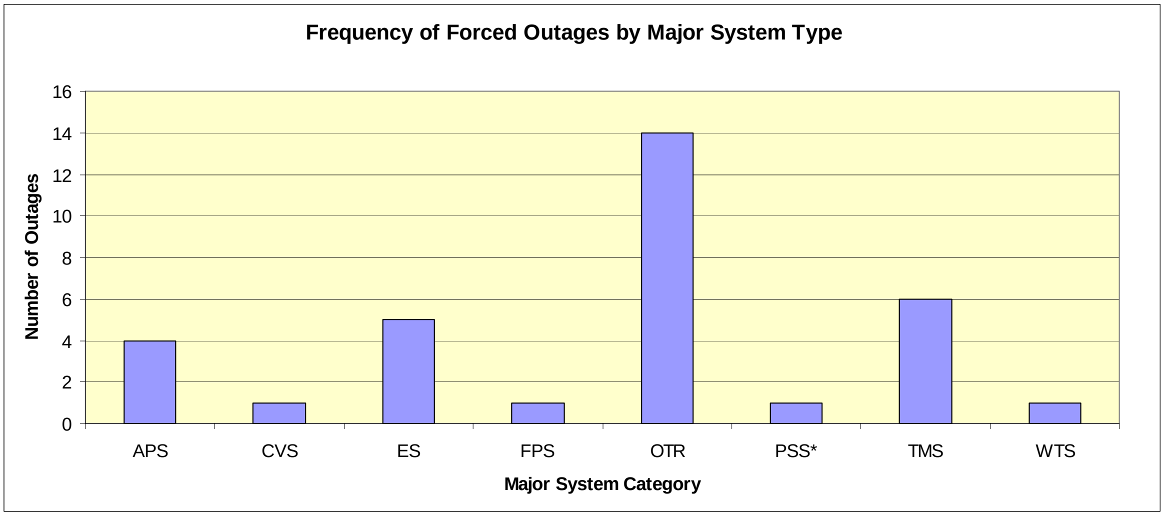


Figure 14. Forced outage occurrences by major system types.

Figure 15 shows the average duration of forced outage hours by major system category. The Thermal Management System (TMS) had the longest average duration at 765.7 hours per outage. The TMS accounted for 6 outages and a total of 4,594.4 hours. The shortest TMS outage was 60.1 hours (temperature control valve: TCV400) and the longest outage was 2,746.3 hours (flow switch: FS400).

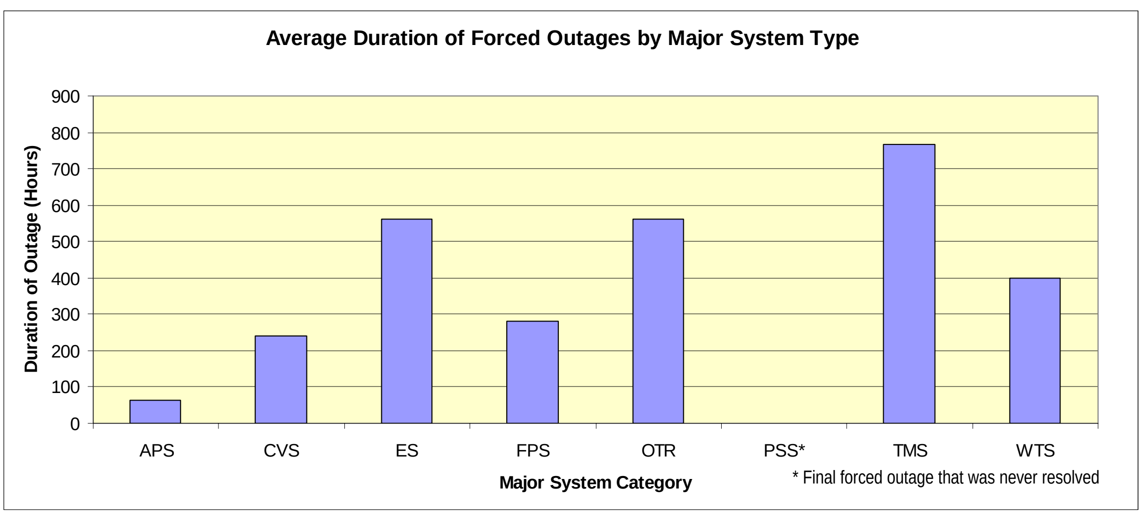


Figure 15. Average forced outage durations by major system types.

The outages that occurred most frequently for a specific fuel cell component were the motorized circuit breakers (MCB) and the air flow transmitter (FT140). During the demonstration, each of the three MCBs failed and accounted for a total of 1,485.9 hours of fuel cell outage. In addition, FT140 attributed to three forced outages for a combined duration of 695.4 hours.

These data show that forced outages have a significant impact on the availability of the fuel cell. The shortest outage lasted for 0.55 hours, and five outages lasted less than 24 hours. Of nine total outages with durations over 30 days, three lasted more than 90 days. Figure 16 shows the distribution of outages by their duration.

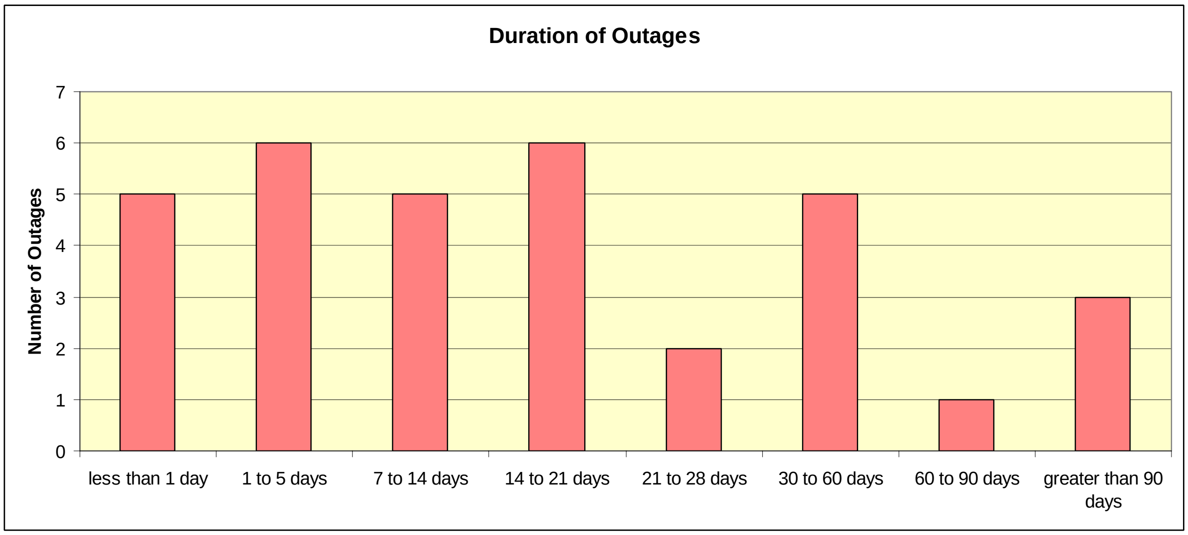


Figure 16. Number of forced outages by outage duration.

Figure 17 shows the total hours of forced outage based on the major system category with the OTR at 48 percent and TMS at 28 percent.

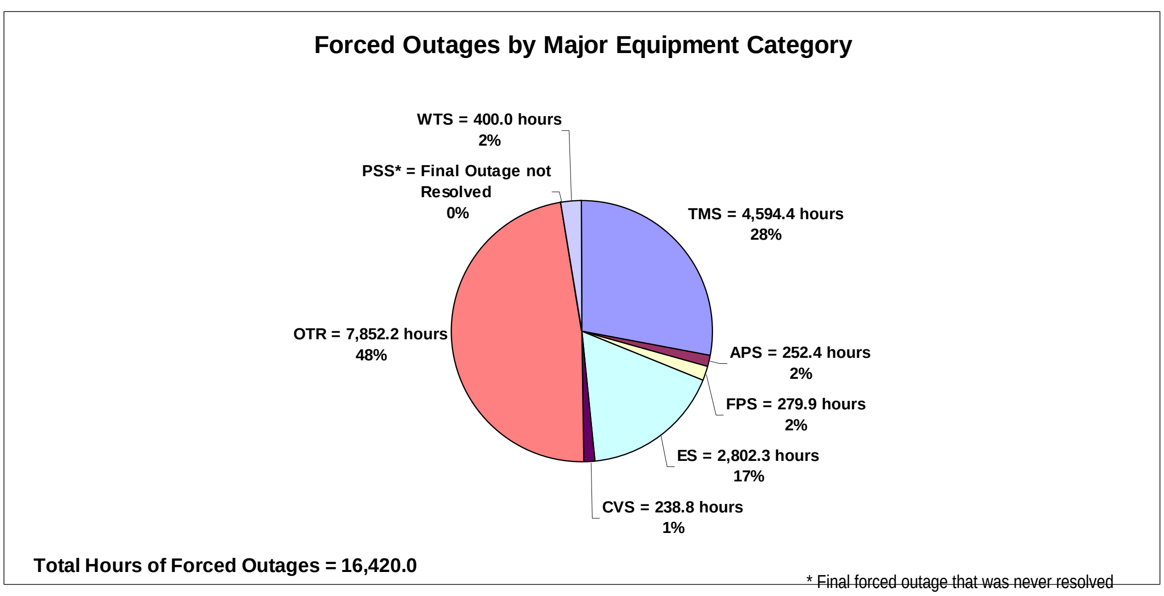


Figure 17. Total forced outage hours by major system types.

4.3 Fuel Cell Stack Degradation

The trend of the fuel cell electrical efficiency based on the lower heating value (LHV) of natural gas was analyzed based on the hours of fuel cell operation. The data was acquired through the UTC Fuel Cells' RADAR system. Data records are for fuel cell operation when the electrical output was greater than 50 kW in order to eliminate data from fuel cell testing and startup operation. Note that the data records were not recorded on regular intervals and 3,126 data points were used for this analysis. Figure 18 charts the individual data points with hours of operation in an X-Y plot. For this data set, the average LHV electrical efficiency is 36.0 percent.

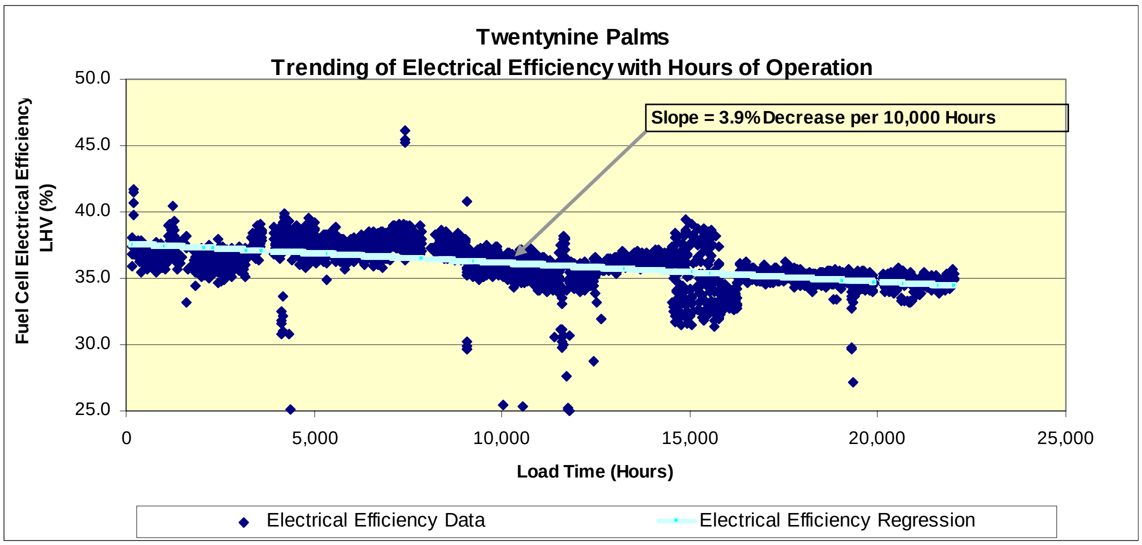


Figure 18. Fuel cell stack electrical efficiency degradation over time.

A linear regression was conducted on the data to characterize average efficiency trends for the fuel cell. The regression equation is:

$$\text{Electric Efficiency \% (LHV)} = ((\text{Load Hours}) \times (-1.42574 \times 10^{-4})) + 37.54944$$

The linear curve fit shows a trend of reduction in electrical efficiency with increasing hours of operation. Table 12 lists the resulting efficiencies at 5,000 load hour intervals.

Table 12. Trend of electrical efficiency with fuel cell load hours.

Load Hours	Electrical Efficiency LHV (%)
0	37.55
5,000	36.84
10,000	36.12
15,000	35.41
20,000	34.70
25,000	33.99

The data in Table 12 show that the fuel cell electrical efficiency decreased 1.42 basis points for every 10,000 hours of operation. The regression shows that the average initial electrical efficiency of the fuel cell was approximately 37.55 percent and it decreased at a rate of approximately 3.9 percent per 10,000 hours of operation. For example, the average decrease between 10,000 hours (36.12 percent) and 20,000 hours (34.70 percent) is:

$$3.9\% = ((36.12\% – 34.70\%) / 36.12\%)$$

The R Square statistic for the above regression is 0.21. This means that 21 percent of the variation seen in the trend of electrical efficiency can be attributed to load hours. Thus other factors in the system significantly affect the changes observed in electrical efficiency. The efficiency data shown in Figure 10 indicate that there are sub-trends in electrical efficiency within the life of the fuel cell's operation. Figure 19 shows the outages and identification of major system changes. Each of the 36 outages is represented as a circle on the 40 percent efficiency line. The figure identifies five major system changes that correspond to establishing a distinct electrical efficiency trend. The number identifier presented for the change corresponds to the outage number as listed in Table 9. The most significant changes were the installation of a new cell stack (#4), the installation of an external reverse osmosis (RO) water treatment system (#8), and the installation of a new fuel valve (#15). The six operational regions in Figure 11 were analyzed to determine the electrical efficiency trend by major system change. The trend in efficiency for each region was determined by a linear regression and the slope is reported in terms of percent change per 10,000 hours of operation. Note that the unit of percent change per 10,000 is presented for consistency and none of the regions evaluated consists of 10,000 hours of data. Table 13 lists the dates, fuel cell load hours, system changes and electric efficiency trends for each of the time frames.

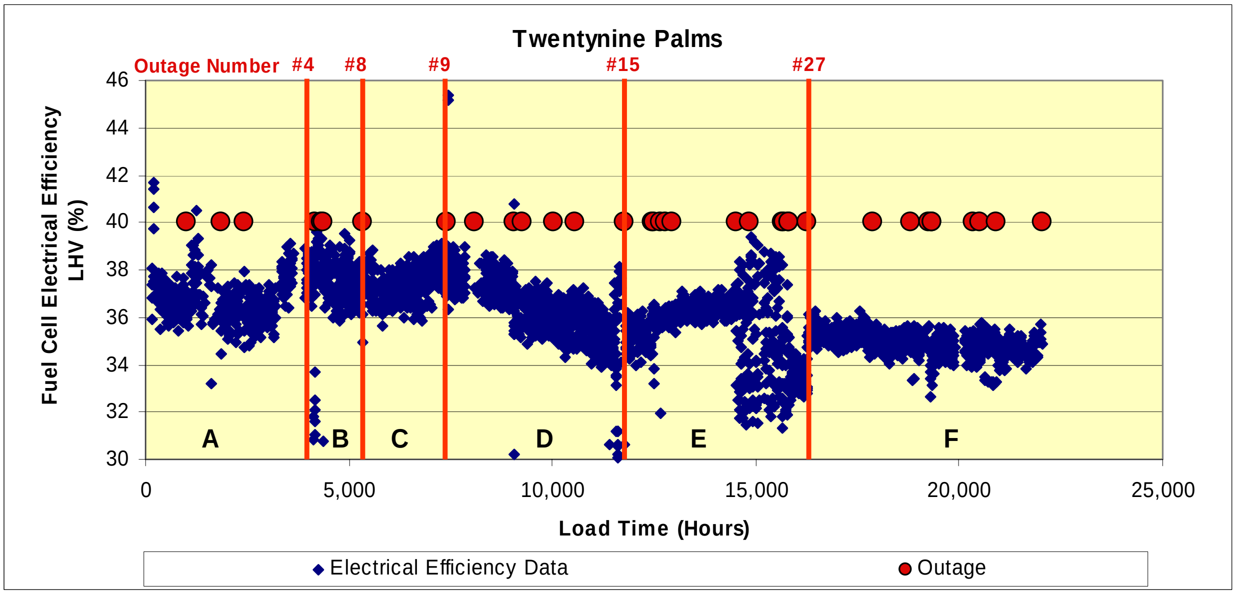


Figure 19. Electric efficiency trends with major system changes.

Table 13. Major system changes and electrical efficiency trends.

Range	Date	Fuel Cell Load hrs at End of Period	Change to System at Start of Period	Slope (% / 10000 hrs)
A	6/20/95 – 4/17/96	4,174	Initial System	No Trend
B	4/17/96 – 8/9/96	5,350	Install new cell stack	-1.8%
C	8/9/96 – 11/6/96	7,420	Install RO water treatment	12.7%
D	11/6/96 – 6/5/97	11,782	Repair coolant flow leak in TMS	-23.4%
E	6/5/97 – 12/15/98	16,262	Install new fuel valve	No Trend
F	12/15/98 – 5/20/00	22,033	Install new heat exchangers	-4.6%

Ranges A and E do not have a distinct electrical efficiency trend over the entire region and no major system changes occurred within the time range. The system changes that occurred around 15,000 hours in region E were mostly electrical system replacements including the UPS, circuit breakers, and a motorized circuit breaker. The average electrical efficiency in region B (37.4 percent), after the installation of the new cell stack, is greater than the average electrical efficiency in range A (36.6 percent). The trend in electrical efficiency in region C is an increase in efficiency over the range indicating that the installation of the external RO water treatment system had a positive impact on fuel cell performance by reducing and avoiding scaling within the thermal management system. Range D shows a strong decreasing trend of electrical efficiency after the repair of a coolant flow leak. It is not anticipated that this would result in an accelerated decrease in efficiency. The malfunctioning fuel valve that was replaced at outage #15 could possibly explain the trend. The trend in region F shows an anticipated gradual decrease in efficiency as the hours of operation are increasing. Overall, with the data available it is difficult to make a definitive conclusion with respect to the trend of electrical efficiency with load hours.

The trend of the fuel cell stack cell voltage was analyzed based on the hours of fuel cell operation. The data is based on the same readings acquired through the UTC Fuel Cells' RADAR system as the electrical efficiency presented above. The individual data points are plotted with hours of operation in an X-Y plot (Figure 20). The average cell voltage for the data is 0.633 volts.

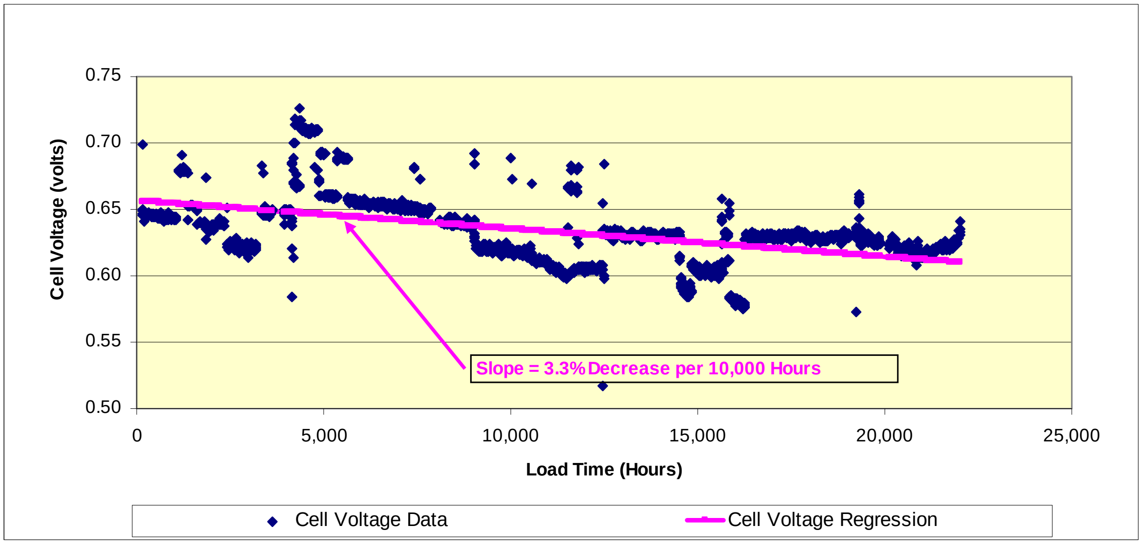


Figure 20. Fuel cell stack cell voltage degradation over time.

A linear regression was conducted on the data to characterize average cell voltage trends for the fuel cell. The resulting equation is:

$$\text{Cell Volts} = ((\text{Load Hours}) \times (-2.1071 \times 10^{-6})) + 0.656387 \qquad \text{Eq. 1}$$

The regression shows a reduction in cell voltage with increased hours of operation. Table 14 lists the resulting cell voltages at 5,000 load hour intervals.

Table 14. Trend of cell voltage with fuel cell load hours.

Load Hours	Cell Voltage
0	0.656
5000	0.646
10,000	0.653
15,000	0.625
20,000	0.614
25,00	0.604

The fuel cell's cell voltage decreased at a rate of 0.021 volts per 10,000 hours of operation. The linear curve fit shows that the initial cell voltage was approximately 0.656 volts and that it decreased at an average rate of 3.3 percent per 10,000 hours of operation. For example, the average decrease between 10,000 hours (0.635) and 20,000 hours (0.614) is:

$$3.3\% = ((0.635 - 0.614) / 0.635)$$

The R Square statistic for the above regression is 0.27. This means that 27 percent of the variation seen in the trend of cell voltage can be attributed to load hours. Thus, other factors in the system are significantly affecting the changes observed in cell voltage. The cell voltage data (Figure 20) show that there are sub-trends in cell voltage during the life of the fuel cell's operation. Since the cell voltage is affected by the electrical output of the fuel cell, an additional analysis was conducted. The data was sorted by the fuel cell electric output for the most frequent operating levels of 200 kW, 175 kW, 150 kW and 125 kW. Then a linear regression was conducted for load hours greater than 5,000 hours (i.e., for the fuel cell after the stack was replaced). The results of the analysis are listed in Table 15.

Table 15. Cell voltage analysis by electrical output.

Fuel Cell Output	200 kW	175 kW	150 kW	125 kW
Data points	1075	126	336	823
R Square Statistic	0.80	0.53	0.45	0.88
Slope (%/10,000 hrs)	-13.9%	-12.3%	-5.2%	-6.2%

The analysis shows that the curve fit was very good for the 200 kW and 125 kW regressions with R Squared values of 0.8 and 0.88 respectively. This indicates that 80 to 88 percent of the decrease in cell voltage can be attributed to load hours for these data sets. The 175 kW and 150 kW regressions have R Squared values of approximately 0.50 indicating that approximately 50 percent of the decline in the cell voltage can be attributed to the load hours for this data set. This is still an improved model of predictor to the original regression model. The slopes of the lines for the 200 kW and 175 kW power levels are significantly higher than the 150 kW and 125 kW levels. The reason for the difference cannot be explained by the lower number of data points at the 150 kW level since there are a significant number of data points at the 125 kW level. Figure 21 shows the regression lines of the analysis for each data set projected over the entire fuel cell operating range.

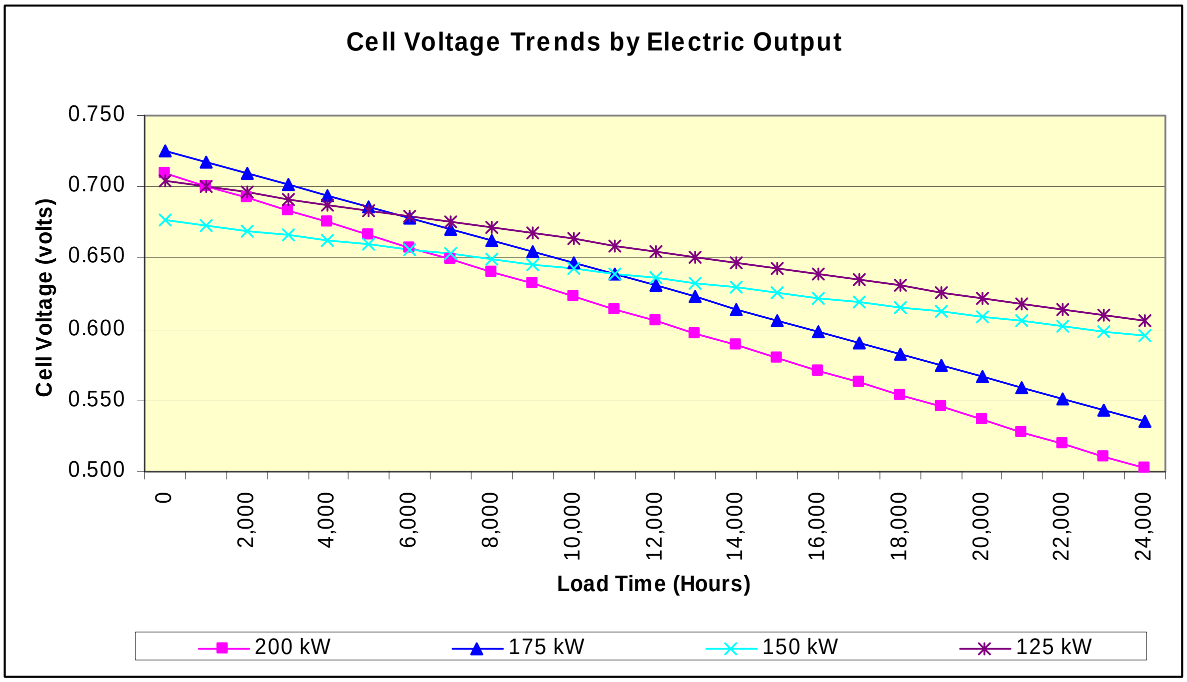


Figure 21. Cell voltage trends by electric output.

While the efficiency remains relatively constant along the various fuel cell power levels, power plant cell voltages tend to increase at lower electric output levels. This is most evident for fuel cell operation greater then 11,000 load hours. There is no data to indicate why the slope of the data varies at the different power levels.

4.4 Fuel Cell Maintenance Activities

UTC Fuel Cells had overall responsibility for maintenance on the fuel cell during the 5-year demonstration period. GBC Electrical Services, as the maintenance contractor, performed most maintenance activities under the guidance of UTC Fuel Cells.

Invoices from GBC Electrical Services were obtained to assess maintenance activity levels. GBC Electrical Services is actually located in Twentynine Palms which meant that there was no extensive travel required for maintenance activities. Table 16 lists the number of maintenance days at the site and total labor hours by year.

Table 16. Maintenance days and labor hours by year.

Year	Days at Site	Labor Hrs.
1995	6	22.5
1996	60	605.0
1997	35	249.5
1998	58	401.5
1999	45	293.0
2000	13	76.5
Total	217	1,648

Tables 17 through 22 list the date, labor hours and a brief description of the maintenance activities that were billed between the years 1995 and 2000.

Table 17. Maintenance activities in 1995.

1995	Labor Hrs	Description of Activity
2-Nov	7.0	Started fuel cell using catalyst reduction procedure
8-Nov	1.0	Performed water conductivity test at HV-453 and HV-431
16-Nov	1.0	Performed water conductivity test at HV-453, HV-452 and HV-431
11-Dec	10.0	Performed water conductivity test at HV-453, HV-452 and HV-431; recharged resin bottles
13-Dec	2.5	Performed voltage test using sub stack voltage measurement box (150 kW & 200 kW)
28-Dec	1.0	Performed water conductivity test at HV-453 and HV-431

Table 18. Maintenance activities in 1996.

1996	Labor Hrs	Description of Activity
13-Jan	2.0	Checked fuses and replaced one blown fuse; checked amps on each phase
14-Jan	2.0	Problem with stack voltage; power level reduced to 100 kW and then shut down fuel cell
26-Jan	5.0	Preparation for steam cleaner
29-Jan	8.5	Preparation for steam cleaner
30-Jan	10.0	Preparation for steam cleaner
31-Jan	10.5	Preparation for steam cleaner
2-Feb	11.0	Preparation for removal of fuel cell stack
3-Feb	10.0	Continued with cell stack wet-up procedures in preparation for removal
5-Feb	9.0	Continued with cell stack wet-up procedures in preparation for removal
6-Feb	18.0	Continued with cell stack wet-up procedures in preparation for removal
8-Feb	26.0	Fuel cell stack removed and secured in shipping crate
21-Mar	8.0	Preparation for Water Treatment System (WTS) cleaning

1996	Labor Hrs	Description of Activity
22-Mar	10.0	Flush fuel cell Water Treatment System
23-Mar	10.0	Continue with Water Treatment System cleaning
25-Mar	10.0	Continue with Water Treatment System cleaning
26-Mar	89.0	Continue with Water Treatment System cleaning
27-Mar	9.0	Continue with Water Treatment System cleaning; prepare for arrival of new fuel cell stack
28-Mar	23.0	Receive and install new fuel cell stack
29-Mar	8.0	Continue with Water Treatment System cleaning
1-Apr	9.0	Continue with Water Treatment System cleaning
2-Apr	17.0	Continue with Water Treatment System cleaning
3-Apr	14.0	Complete flushing of Water Treatment System
9-Apr	9.5	Install ***retrofits*** with UTC Fuel Cells
10-Apr	10.0	Install ***retrofits*** with UTC Fuel Cells
11-Apr	14.0	Install ***retrofits*** with UTC Fuel Cells
12-Apr	10.0	Install ***retrofits*** with UTC Fuel Cells
15-Apr	7.5	Start-up fuel cell
16-Apr	6.0	Repair heater 400
17-Apr	10.0	Start fuel cell with reduction process
18-Apr	12.0	Finish details and adjust new valve 400
19-Apr	12.5	Final setting on valve 400
20-Apr	3.0	Testing of grid-independent capability during site outages; ramp up fuel cell to 200 kW
27-Apr	6.5	Attempted to restart fuel cell several times and conducted water sampling; reformer burner (BE030) malfunctioning
3-May	8.5	Repair process steam control valve (CV500) and start fuel cell
4-May	3.5	Attempted to restart fuel cell
13-May	4.0	Worked on electrical systems
12-Jun	4.5	Prepared to install reverse osmosis unit
13-Jun	6.0	Modifications made to Water Treatment System
14-Jun	8.5	Start-up fuel cell
17-Jun	6.5	Replace circuit breaker and relay
18-Jun	5.0	Start fuel cell
19-Jun	6.5	Conduct water testing
8-Jul	9.0	Water recovery testing
9-Jul	9.0	Water recovery testing
10-Jul	9.0	Water recovery testing
11-Jul	8.0	Install reverse osmosis unit
12-Jul	7.0	Install reverse osmosis unit
16-Jul	7.5	Install reverse osmosis unit
17-Jul	9.0	Install reverse osmosis unit electrical
18-Jul	14.0	Install reverse osmosis unit enclosure
19-Jul	7.0	Install reverse osmosis unit and initiate operation
9-Aug	9.5	Start fuel cell
22-Aug	6.0	Increase power level to 200 kW and perform water testing

1996	Labor Hrs	Description of Activity
4-Nov	4.0	Troubleshooting
6-Nov	8.0	Replace module and start
7-Nov	2.0	Increase power level and conduct water testing
12-Nov	8.0	Change out resin and charcoal
13-Nov	1.0	Conduct water testing
3-Dec	6.0	Restart power plant
7-Dec	8.0	Restart power plant

Table 19. Maintenance activities in 1997.

1997	Labor Hrs	Description of Activity
17-Jan	9.0	Troubleshot circuit breaker K002
18-Jan	7.0	Changed relay K2, cleaned fire eye and attempted to start fuel cell
21-Jan	11.5	Attempted to start fuel cell
22-Jan	12.0	Attempted to start fuel cell
23-Jan	8.0	Trouble shooting system
24-Jan	6.0	Trouble shooting system and replace fire eye
27-Jan	1.0	Change out Water Treatment System bottles
28-Jan	10.0	Changed pump 451 and started fuel cell
8-Feb	7.5	Restart fuel cell
11-Mar	9.0	Quarterly maintenance and change our resin
12-Mar	7.0	Restart fuel cell
3-Apr	10.0	Worked on leaks and restarted fuel cell
1-May	3.5	Attempted to fix leak on discharge side of pump 451
29-May	2.0	Trouble shot flow control valve (FCV012)
5-Jun	36.0	Perform annual maintenance and install new fuel valve
7-Jul	5.0	Changed out pump 451 and checked valve 541
8-Jul	5.0	Attempted to start fuel cell (FCV140 stuck)
9-Jul	7.0	Replace FCV140 and attempted to start fuel cell unsuccessfully
10-Jul	2.0	Tested FT140 and identified that part failed
11-Jul	5.0	Replaced FT140 and attempted to start fuel cell unsuccessfully
12-Jul	7.0	Cleaned fire eye and restarted power plant
24-Jul	4.0	Worked with UTC Fuel Cells personnel at site
4-Aug	4.0	Worked with UTC Fuel Cells personnel at site
5-Aug	8.0	Worked with UTC Fuel Cells personnel at site
6-Aug	6.0	Changed union F0420
12-Aug	5.0	Worked with UTC Fuel Cells personnel at site
13-Aug	8.0	Worked with UTC Fuel Cells personnel at site
15-Aug	4.5	Worked with UTC Fuel Cells personnel at site
2-Sep	1.0	Put power plant back in water conditioning mode
16-Sep	7.5	Removed old batteries from UPS and found that the replacements were wrong
18-Sep	7.5	Changed batteries in UPS and changed nitrogen bottles

1997	Labor Hrs	Description of Activity
23-Sep	8.0	Drained water from fuel cell; removed and reinstalled pump 451 and put power plant in water conditioning
24-Sep	7.5	Attempted to start fuel cell unsuccessfully and troubleshot failure
30-Sep	4.0	Cleaned fire eye and restarted power plant
26-Dec	4.0	Attempted to start the fuel cell

Table 20. Maintenance activities in 1998.

1998	Labor Hrs	Description of Activity
5-Jan	3.0	Troubleshot circuit breaker CB002
20-Jan	17.0	Remove and replace pump 820
22-Jan	7.0	Installed motor controller and started power plant
23-Jan	11.0	Troubleshot shutdown, replaced FCV012 and started power plant
27-Feb	8.0	Changed resin and charcoal bottles
16-Mar	6.0	Drained the system; put new O-rings in FCU400 and refilled the system
17-Mar	8.5	Started fuel cell
18-Mar	1.0	Attempted to restart power plant
24-Mar	6.0	Replaced circuit breaker mechanisms and restarted power plant
26-Mar	13.0	Checked wiring in CB K001, K002 & K003 and replaced I/O modules and relays
6-Apr	2.0	Troubleshot UPS problem
9-Apr	16.0	Removed and replaced UPS and started power plant
14-Apr	3.0	Removed and replaced panels from fuel cell
16-Apr	5.5	Installed PC7 ribbon cable; started power plant; changed out nitrogen bottles
20-Apr	3.0	Worked with UTC Fuel Cells on phone as they could not communicate directly with fuel cell
8-May	4.0	Troubleshot communications problem
11-May	12.0	Changed out MCB003; started power plant; conducted cell stack tests at idle, 100 kW and 150 kW
12-May	4.0	Worked with UTC Fuel Cells on phone; took cell stack readings
18-May	10.0	Took out J pipes and put in bypass pipes; took out BP440 and put in bypass
19-May	16.0	Started steam cleaning and conducted water testing
20-May	19.0	Steam cleaning and water testing
21-May	2.0	Steam cleaning and water testing
22-May	10.0	Steam cleaning and water testing
26-May	6.0	Cleaned cell stack assembly (CSA)
27-May	12.0	Cleaned cell stack assembly (CSA)
28-May	9.0	Cleaned cell stack assembly (CSA)
29-May	10.0	Cleaned cell stack assembly (CSA)
2-Jun	6.0	Cleaned and greased fittings
3-Jun	8.0	Changed SAC metals
4-Jun	12.0	Cleaned wire box, etc.
5-Jun	7.0	Put fuel cell back together
8-Jun	8.0	Worked with UTC Fuel Cells personnel at site
9-Jun	13.0	Worked with UTC Fuel Cells personnel at site
10-Jun	7.0	Worked with UTC Fuel Cells personnel at site

1998	Labor Hrs	Description of Activity
11-Jun	8.5	Worked with UTC Fuel Cells personnel at site
12-Jun	4.0	Worked with UTC Fuel Cells personnel at site
16-Jun	8.0	Worked with UTC Fuel Cells personnel at site
17-Jun	5.0	Worked with UTC Fuel Cells personnel at site
18-Jun	2.0	Worked with UTC Fuel Cells personnel at site
19-Jun	4.0	Worked with UTC Fuel Cells personnel at site
23-Jun	12.0	Ran chemicals through reverse osmosis unit to clean in place; replaced final pressure gauge
24-Jun	5.5	Started reverse osmosis unit and replaced filter
2-Jul	2.0	Conducted grid connect/grid-independent test
31-Jul	2.0	Conducted grid connect/grid-independent test
28-Aug	2.0	Conducted grid connect/grid-independent test
15-Sep	1.0	Checked to make sure cooling fans were on and working
16-Sep	2.0	Reset logic so cooling fans would cool stack; flushed reverse osmosis unit for 15 minutes
28-Sep	2.0	Put fuel cell back into water conditioning; flushed reverse osmosis system
30-Sep	4.5	Worked with UTC Fuel Cells personnel at site
1-Oct	9.5	Worked with UTC Fuel Cells personnel at site; install two heat exchangers
2-Oct	9.0	Worked with UTC Fuel Cells personnel at site; install two heat exchangers
3-Oct	4.5	Worked with UTC Fuel Cells personnel at site
23-Oct	2.0	Conducted grid connect/grid-independent test
5-Nov	2.0	Install modem cable
6-Nov	2.0	Troubleshot lockout relay
14-Dec	4.5	Changed flow meter and attempted to start power plant
15-Dec	10.5	Turned gas on and cleaned fire eye; started power plant and did two shift reducing tests
16-Dec	8.0	Tuned power plant; restarted power plant after gas outage

Table 21. Maintenance activities in 1999.

1999	Labor Hrs	Description of Activity
22-Feb	4.0	Checked bottom of cell stack looking for acid residue
23-Feb	6.0	Checked bottom of cell stack looking for acid residue
25-Feb	17.0	Prepared fuel cell for megohmmeter test; repaired water leak at reverse osmosis unit
26-Feb	7.0	Isolated cell stack and tested with megohmmeter
9-Mar	10.0	Troubleshot short in cell stack assembly
10-Mar	9.0	Continued looking for leak in CSA manifold and cleaned area
11-Mar	4.0	Retested CSA for short
12-Mar	2.0	Retested CSA for short; placed a space heater in CSA area to dry water from cleaning
16-Mar	11.0	Had CSA patch modified to fit; installed patch and retested CSA
5-Apr	4.0	Worked on CSA base insulators
6-Apr	18.0	Installed base insulators; reassembled CSA and cabinet; started power plant
19-May	1.0	Troubleshot hot shut down; put power plant in cool down
20-May	12.0	Troubleshot FT140 shutdown; repaired leaks in water treatment system; started power plant
21-May	3.5	Changed water treatment system bottles

4-Jun	7.0	Troubleshot FT140 and attempted to fix leak on FO420 union; left power plant in P15
8-Jun	2.0	Replaced FT140 and took apart FO420
9-Jun	3.0	Worked with welder
10-Jun	6.0	Attempted to start power plant
11-Jun	8.0	Attempted to start power plant
14-Jun	9.0	Attempted to start power plant
15-Jun	6.5	Troubleshot TCV400
16-Jun	7.5	Rebuilt TCV400
18-Jun	13.0	Attempted to start power plant; replaced TCV400.
17-Jul	1.0	Put power plant back in water conditioning
21-Jul	2.0	Replaced PC19 card; put power plant back in water conditioning
10-Aug	8.0	Troubleshot FT140
11-Aug	12.0	Attempted to start power plant
12-Aug	9.0	Cleaned fire eye and attempted to start power plant
13-Aug	5.5	Attempted to start power plant
20-Aug	8.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
24-Aug	7.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
25-Aug	8.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
26-Aug	10.0	Attempted to start power plant; worked with UTC Fuel Cells on phone
27-Aug	5.0	Attempted to start power plant; found bad valve FCV140
31-Aug	13.0	Attempted to start power plant; changed brakes on FCV110; worked with UTC Fuel Cells on phone
1-Sep	4.0	Attempted to start power plant
2-Sep	8.0	Changed Filter 100; started power plant and left at 125 kW
9-Sep	3.0	Changed out water treatment system bottles
14-Oct	2.0	Analyzed the modem and made sure it was operating properly
15-Oct	2.0	Worked with UTC Fuel Cells on phone
17-Oct	1.0	Put power plant back in water conditioning
18-Oct	2.0	Attempted to start power plant; leak detected and shut down power plant
1-Nov	9.0	Repaired pump 450 water leak; started power plant
3-Dec	2.0	Rerouted conductivity sensor for DMN450 bottles
12-Dec	1.0	Troubleshot pump 400

Table 22. Maintenance activities in 2000.

2000	Labor Hrs	Description of Activity
6-Jan	1.0	Removed old 50 amp breaker
18-Jan	1.0	Installed 50 amp breaker for heater 400
19-Jan	6.0	Changed heater 400
20-Jan	8.5	Flushed system
21-Jan	8.0	Attempted to start power plant; troubleshot failed start
24-Jan	9.5	Troubleshot FO400 and attempted to start power plant
27-Jan	8.0	Rebuilt CV500 and attempted to start power plant

2000	Labor Hrs	Description of Activity
28-Jan	5.0	Worked with UTC Fuel Cells on phone; checked FO420, flow orifices and leak down on water tank
10-Feb	7.0	Changed out FS400 and FO420/440
11-Feb	6.0	Started power plant and power plant shutdown
15-Feb	5.0	Troubleshot FS400 problem
31-Mar	3.0	Changed out FS400
3-Apr	8.5	Started power plant

4.5 Fuel Cell Retrofits

As part of the fuel cell demonstration and overall fuel cell development, UTC Fuel Cells refined the fuel cell design based on operational experience gained through the operation of the fleet of fuel cells. These improvements and modifications were classified as retrofits. Once a retrofit was developed, it would be incorporated into the production of new fuel cells or retrofit in the field for installed fuel cells. The details of the retrofits are considered proprietary information by UTC Fuel Cells and are not available for this report. The data in Tables 17 through 22 show that the only retrofit that was added to the fuel cell in the field was during 9 –12 April 1996. At this time there was a modification to the Thermal Management System to modify piping and a flow control valve. The objective of the retrofit was to increase the rate of heat transfer off the stack so the appropriate stack temperature could be maintained when the level of heat generated by the stack increases toward the end of the stack life.

4.6 Fuel Cell Operation and Outage Summary

Appendix E shows the operational and outage periods for each hour within the 60 months that the fuel cell was active (June 1995 to May 2000). The outage times are highlighted in gray along with a listing of the outage number, duration in hours and minutes, and a brief description of the shutdown. Days where on-site maintenance was performed is shown graphically by an 8-hour box. GBC Electrical Services, the maintenance contractor, provided maintenance activity records.

5 Fuel Cell Economics

5.1 Hospital Energy Costs

The Naval Hospital, as a tenant at MCAGCC Twentynine Palms, pays the Base for its electricity usage. The Base purchases electricity from Southern California Edison (SCE) under a time of use rate schedule, TOU-8. This rate has a summer and winter season consisting of on-peak, mid-peak and off-peak time periods. Table 23 lists the structure of the TOU-8 tariff. The difference between the facility-related demand charge and the time-related demand charges are the method of calculation. The facility-related demand charge is the highest demand over any 15-minute period during the billing period. The time-related demand charge is determined as the highest demand over any 15-minute period for the time periods defined (on-peak, mid-peak and off-peak). Typically, the on-peak demand charge is the highest cost of all the demand charges and the off-peak demand charge is zero.

Table 23. SCE TOU-8 rate structure.

	Summer	Winter
Months	June – September	October – May
On Peak Period	Noon – 6:00 pm	None
Mid-Peak Period	8:00 am – Noon 6:00 pm – 11:00 pm	8:00 am – 9:00 pm
Off-Peak Period	All other hours and holidays	All other hours and holidays
Charges	Facility Charge ($/meter) Energy Charge ($/kWh) Facility-Related Demand Charge ($/kW) Time-Related Demand Charge ($/kW) Excess Transformer Capacity ($/kVA) Power Factor Adjustment ($/kVA)	Facility Charge ($/meter) Energy Charge ($/kWh) Demand Charge ($/kW) Excess Transformer Capacity ($/kVA) Power Factor Adjustment ($/kVA)

The Base purchases natural gas from two sources, a contracted commodity purchase through a gas provider for the central plant and Southern California Gas Company (SoCalGas). The costs that are passed on to the Hospital are the SoCalGas costs, which are billed under tariff GN-20.

Records of the Hospital electric and natural gas consumption were collected from the Base for the period of October 1997 through 2001. Data for the period of June 1995 through September 1997 were not available. Tables 24 through 27 list the data for the periods of FY 98 through FY01 respectively.

Table 24. Hospital energy bills for FY98.

Month	ELECTRICITY Consumption kWh	Costs $	Average Cost $/kWh	NATURAL GAS Consumption Therms	Costs $	Average Cost $/Therm
October 1997	299,240.00	$31,120.96	$0.1040	16,426.00	$9,527.08	$0.5800
November 1997	226,400.00	$23,545.60	$0.1040	17,097.00	$9,916.26	$0.5800
December 1997	223,749.00	$23,269.90	$0.1040	15,964.00	$9,259.12	$0.5800
January 1998	230,189.00	$23,939.66	$0.1040	4,964.00	$2,879.12	$0.5800
February 1998	215,949.00	$22,458.70	$0.1040	19,574.00	$11,352.92	$0.5800
March 1998	496,120.00	$50,455.40	$0.1017	8,936.00	$3,642.49	$0.4076
April 1998	576,360.00	$58,615.81	$0.1017	12,754.00	$5,198.79	$0.4076
May 1998	531,384.00	$54,041.75	$0.1017	11,891.00	$4,847.01	$0.4076
June 1998	534,800.00	$54,389.16	$0.1017	4,884.00	$1,990.82	$0.4076
July 1998	729,840.00	$74,224.73	$0.1017	3,789.00	$1,544.47	$0.4076
August 1998	602,368.00	$61,260.83	$0.1017	3,392.00	$1,382.65	$0.4076
September 1998	738,360.00	$75,091.21	$0.1017	3,506.00	$1,429.12	$0.4076
Total	**5,404,759.00**	**$552,413.71**	**$0.1022**	**123,177.00**	**$62,969.85**	**$0.5112**

Table 25. Hospital energy bills for FY99.

Month	ELECTRICITY Consumption kWh	Costs $	Average Cost $/kWh	NATURAL GAS Consumption Therms	Costs $	Average Cost $/Therm
October 1998	738,360.00	$75,091.21	$0.1017	3,506.00	$1,429.12	$0.4076
November 1998	390,320.00	$39,695.54	$0.1017	6,489.00	$2,645.05	$0.4076
December 1998	403,040.00	$40,989.17	$0.1017	11,868.00	$4,837.63	$0.4076
January 1999	440,384.00	$44,787.05	$0.1017	12,710.00	$5,180.85	$0.4076
February 1999	601,480.00	$61,170.52	$0.1017	10,960.00	$4,467.52	$0.4076
March 1999	474,056.00	$48,211.50	$0.1017	6,784.00	$2,765.29	$0.4076
April 1999	401,744.00	$40,857.36	$0.1017	8,963.00	$3,653.50	$0.4076
May 1999	731,272.00	$74,370.36	$0.1017	10,906.00	$4,445.50	$0.4076
June 1999	268,488.00	$27,305.23	$0.1017	2,321.00	$946.09	$0.4076
July 1999	739,904.00	$75,248.24	$0.1017	5,399.00	$2,200.74	$0.4076
August 1999	765,336.00	$77,834.67	$0.1017	1,361.00	$554.77	$0.4076
September 1999	626,250.00	$63,689.63	$0.1017	4,997.00	$2,036.88	$0.4076
Total	**6,580,634.00**	**$669,250.48**	**$0.1017**	**86,264.00**	**$35,162.94**	**$0.4076**

Table 26. Hospital energy bills for FY00.

Month	ELECTRICITY Consumption kWh	Costs $	Average Cost $/kWh	NATURAL GAS Consumption Therms	Costs $	Average Cost $/Therm
October 1999	635,480.00	$64,628.32	$0.1017	10,005.00	$4,078.24	$0.4076
November 1999	528,448.00	$53,743.16	$0.1017	9,963.00	$4,061.12	$0.4076
December 1999	628,096.00	$63,877.36	$0.1017	10,983.00	$4,476.89	$0.4076
January 2000	531,176.00	$54,020.60	$0.1017	10,080.00	$4,108.81	$0.4076
February 2000	569,184.00	$57,886.01	$0.1017	11,500.00	$4,687.63	$0.4076
March 2000	503,752.00	$51,231.58	$0.1017	7,500.00	$3,057.15	$0.4076
April 2000	455,672.00	$46,341.84	$0.1017	7,000.00	$2,853.34	$0.4076
May 2000	648,536.00	$65,956.11	$0.1017	6,500.00	$2,649.53	$0.4076
June 2000	666,224.00	$67,754.98	$0.1017	3,000.00	$1,222.86	$0.4076
July 2000	574,560.00	$58,432.75	$0.1017	3,000.00	$1,222.86	$0.4076
August 2000	622,968.00	$63,355.85	$0.1017	4,500.00	$1,834.29	$0.4076
September 2000	682,305.00	$69,390.42	$0.1017	4,252.00	$1,733.20	$0.4076
Total	**7,046,401.00**	**$716,618.98**	**$0.1017**	**88,283.00**	**$35,985.92**	**$0.4076**

Table 27. Hospital energy bills for FY01.

Month	ELECTRICITY Consumption kWh	Costs $	Average Cost $/kWh	NATURAL GAS Consumption Therms	Costs $	Average Cost $/Therm
October 2000	620,440.00	$63,098.75	$0.1017	6,931.00	$4,851.70	$0.7000
November 2000	509,856.00	$51,852.36	$0.1017	3,573.00	$2,501.10	$0.7000
December 2000	622,712.00	$63,329.81	$0.1017	10,550.00	$7,385.00	$0.7000
January 2001	538,968.00	$54,813.05	$0.1017	5,256.00	$3,679.20	$0.7000
February 2001	480,480.00	$48,864.82	$0.1017	11,500.00	$8,050.00	$0.7000
March 2001	515,000.00	$52,375.50	$0.1017	11,500.00	$8,050.00	$0.7000
April 2001	524,000.00	$78,600.00	$0.1500	8,000.00	$7,600.00	$0.9500
May 2001	581,936.00	$87,290.40	$0.1500	8,000.00	$7,600.00	$0.9500
June 2001	581,672.00	$87,250.80	$0.1500	8,000.00	$7,600.00	$0.9500
July 2001	620,984.00	$93,147.60	$0.1500	8,000.00	$7,600.00	$0.9500
August 2001	489,488.00	$73,423.20	$0.1500	8,000.00	$7,600.00	$0.9500
September 2001	553,231.00	$82,984.65	$0.1500	8,000.00	$7,600.00	$0.9500
Total	**6,638,767.00**	**$837,030.94**	**$0.1261**	**97,310.00**	**$80,117.00**	**$0.8233**

Figure 14 shows the annual trend in Hospital electric consumption and Figure 15 shows the annual trend in Hospital natural gas consumption.

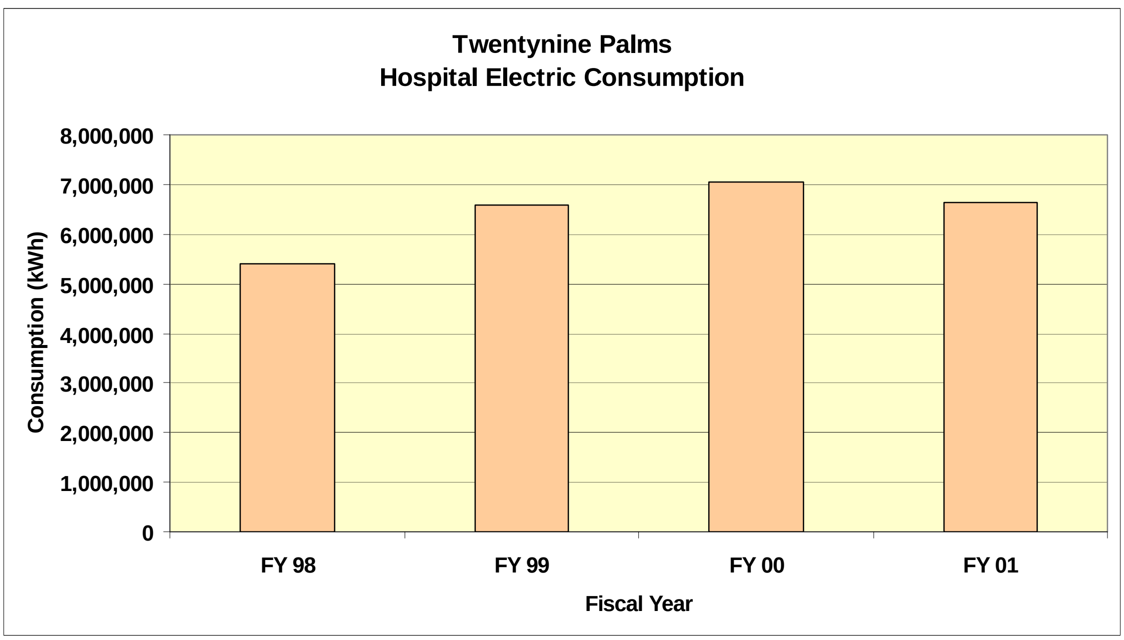


Figure 22. Annual hospital electric consumption.

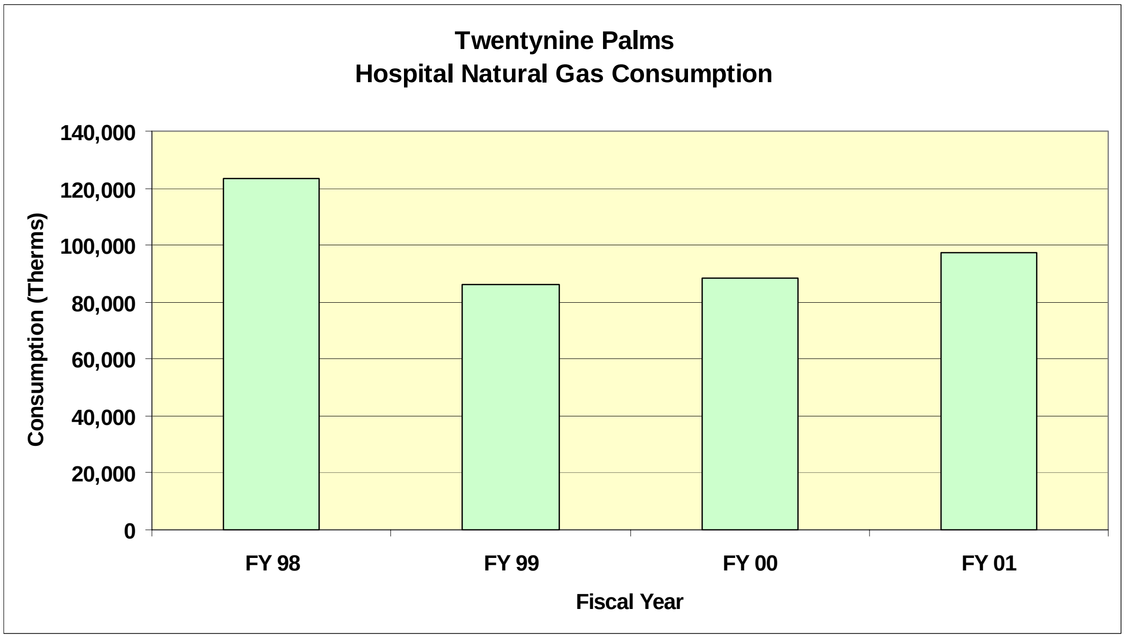


Figure 23. Annual hospital natural gas consumption.

5.2 Fuel Cell Maintenance Costs

Table 28 lists the maintenance costs for services provided by GBC Electrical Services between 1995 through the end of the demonstration project. Labor was the highest cost category at $76,969. Labor hours averaged 330 work-hours per 12 months. The highest number of work-hours in a calendar year was 605 in 1996. Nitrogen costs totaled $21,472. Spread across the 36 outages that occurred, this averages $596 per outage. While charcoal used in the water treatment system was a relatively minor cost (~$500/year), resin was a significant program cost totaling nearly $25,000. A bed of ion-exchange resin is used to soften the water in the water treatment system. The softening process exchanges calcium and magnesium ions in the water for sodium ions in the resin. Resin costs work out to approximately $1,120 per one thousand operating hours. Appendix F presents maintenance costs by Invoice date.

Table 28. Summary of fuel cell maintenance costs.

CATEGORY	1995	1996	1997	1998	1999	2000	TOTALS
Labor Hours	22.5	605	249.5	401.5	293	76.5	**1,648**
Labor Costs	$968	$24,598	$12,475	$18,925	$15,772	$4,233	**$76,969**
Nitrogen Costs	$1,188	$6,459	$6,422	$3,100	$3,285	$1,018	**$21,472**
Charcoal (cu. ft.)	0	4	4	4	4	0	**16**
Charcoal Costs	$0	$372	$372	$372	$392	$0	**$1,508**
Resin (cu. ft.)	0	41	27	18	16	0	**102**
Resin Costs	$0	$10,395	$6,102	$4,068	$4,240	$0	**$24,805**
Other Costs	$32	$11,877	$1,485	$1,716	$2,627	$1,746	**$19,484**
Travel Costs	$0	$0	$0	$0	$154	$33	**$187**
Shipping Costs	$34	$122	$572	$304	$0	$0	**$1,031**
TOTALS	**$2,222**	**$53,823**	**$27,428**	**$28,485**	**$26,470**	**$7,029**	**$145,457**

The cost of maintenance over the entire operating period as shown above was $145,457. This corresponds to an average maintenance cost of approximately 4.12 cents/kWh ($145,457/ 3,533,735 kWh) for all the electricity supplied to the Naval Hospital. This represents $29,091/year over the 5-year demonstration period. ***Note that the maintenance costs presented do not include the cost of any parts or equipment provided by UTC Fuel Cells to repair or modify the fuel cell.***

Figure 24 shows the trend in annual maintenance costs for the fuel cell. Note that the costs presented for 1995 and 2000 are for approximately 6 months each as the fuel cell started operation on 20 June 1995 and concluded operation on 26 May 2000. The high costs on 1996 are attributed to the hard water problems and the resulting water treatment system installation.

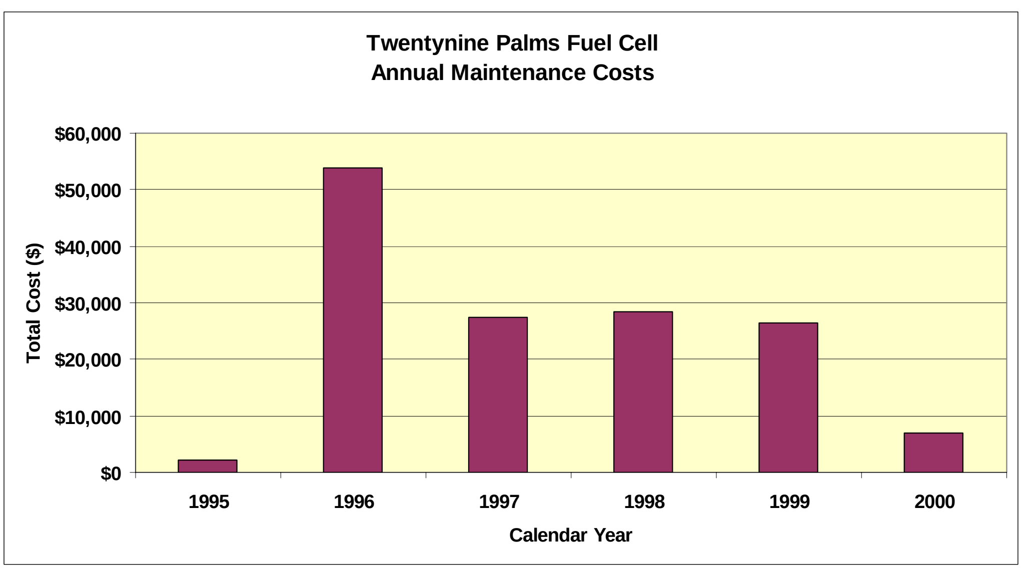


Figure 24. Annual trend in fuel cell maintenance costs.

Fuel cell maintenance costs for the 5-year demonstration period were included in the original purchase contract with the fuel cell manufacturer. First year maintenance costs were included in the original fuel cell purchase price. For the final 4 years of contract maintenance, UTC Fuel Cells was paid $137,200 ($34,300 per year).

5.3 Fuel Cell Energy Savings

Energy savings from the fuel cell were calculated based the Naval Hospital's monthly electric and natural gas energy bills. Average monthly rates were applied to monthly fuel cell electrical and thermal output as well as the input fuel. For periods where electricity and natural gas bills were not available, costs were interpolated. Table 29 lists the annual energy savings delivered by the fuel cell. Net energy savings for this site over the entire program were $131,761.

Table 29. Annual energy savings at naval hospital.

	1995	1996	1997	1998	1999	2000	Total
Electric Savings	$44,369	$67,106	$96,435	$32,278	$53,055	$14,318	$307,560
Thermal Savings	$1,341	$1,949	$2,032	$142	$93	$50	$5,557
Total Savings	$45,710	$69,054	$98,467	$32,420	$53,148	$14,318	$313,118
Natural Gas Costs	$33,418	$42,947	$57,134	$18,003	$23,415	$6,357	$181,273
Net Savings	$12,292	$26,107	$41,333	$14,417	$29,733	$7,961	$131,844

Overall electric savings were $307,560 with a maximum annual savings of $96,435 occurring in 1997. The modest level of thermal heat recovery from the fuel cell and used by the Hospital resulted in a total natural gas savings of $5,557. The value of the recovered heat was greatest in 1997 with savings of $2,032. The cost of natural gas to operate the fuel cell totaled $181,273 over the course of the demonstration. This amount corresponds to a fuel cost for electric generation of $0.0515/kWh ($181,273/3,522,400 kWh). Figure 25 shows the trend in annual energy savings.

5.4 Fuel Cell Lifecycle Costs

The fuel cell lifecycle cost analysis is presented for the operational life of the fuel cell at MCAGCC Twentynine Palms. At the end of the demonstration, the fuel cell was removed. Therefore, the costs and operation in this report cover the entire life of the fuel cell (20 June 1995 — 20 May 2000). Note that the cost of fuel cell removal is not included in the analysis.

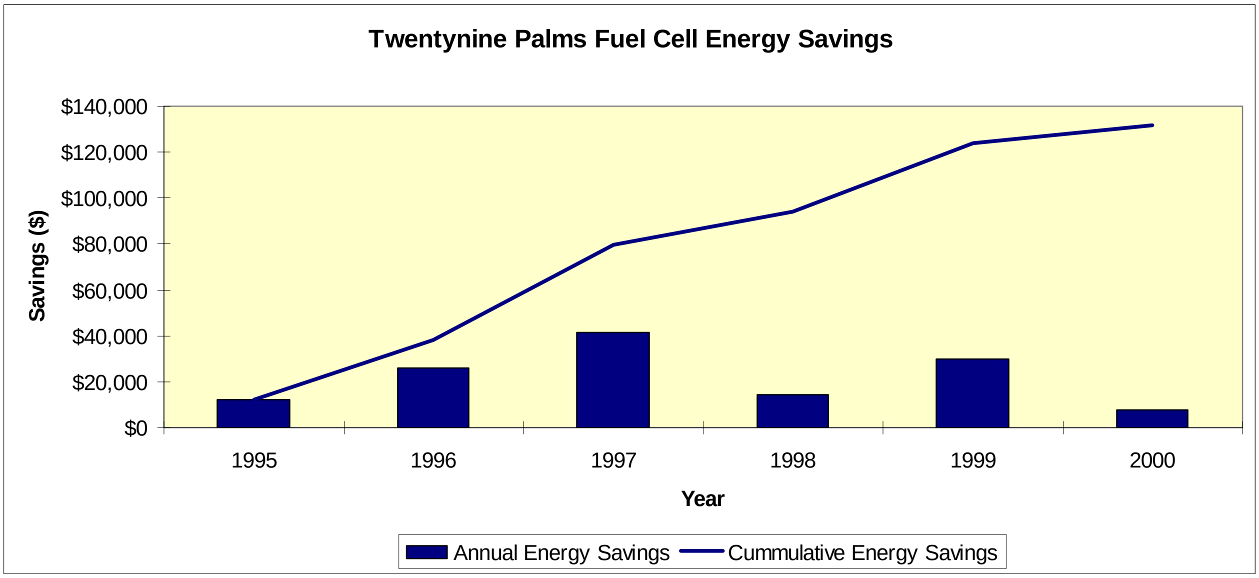


Figure 25. Annual fuel cell energy savings.

The installed cost of the fuel cell was $1,200,000. The lifecycle cost analysis uses the utility rates presented in section 5.1, the maintenance costs presented in section 5.2 and the savings presented in section 5.3. Note that the analysis is based on the average cost of electricity that the Hospital is charged. That is to say that demand savings are not calculated separately in the analysis. A review of the data shows that demand savings would have been realized in only ten of the 59 full months of operation and that the average demand reduction for the 10 months would have been 170.1 kW. The criterion for determining demand savings is that the fuel cell was operational during all hours of the peak period hours for the calendar month. In two cases the fuel cell was down during the month, but the entire outage occurred during non-peak time periods. Table 30 lists the months in which the facility demand savings could have been attributed to the fuel cell and the average output of the fuel cell during the month. Note that for the SCE TOU-8 tariff that the peak demand is applicable during the months of June through September. The data in Table 30 show that the peak demand savings would have occurred on only three of the months, July 1995, August 1995, and September 1996.

Table 30. Fuel cell demand savings.

Month of Demand Savings		Fuel Cell Demand Savings
July	1995	200
August	1995	143
December	1995	158
September	1996	200
October	1996	200
February	1997	200
October	1997	150
November	1997	150
February	1998	175
January	1999	125
Number of Months		10
Average Demand		170

Data in Table 31 represent the lifecycle cost analysis. The analysis allocates the capital cost of the fuel cell in the 1995 calendar year. In addition, values are actual costs and are not adjusted to a base year. The analysis shows that the operational costs exceeded the savings in 1996 and 1998 and that the cumulative operational savings were negative at the end of the period of analysis.

Table 31. Lifecycle cost analysis.

Year	1995	1996	1997	1998	1999	2000
Hours of Operation						
Operation Hours/Yr.	3,705	4,836	5,970	1,989	4,253	1,136
Total Operation Hours	3,705	8,542	14,512	16,501	20,755	21,890
Hours Since Overhaul	3,705	8,542	14,512	16,501	20,755	21,890
Operation Values						
Electrical Eff (%)	32.4%	33.3%	32.0%	30.6%	31.0%	30.8%
Thermal Eff (%)	3.2%	3.6%	2.9%	0.6%	0.3%	0.0%
Demand Disp. (kW)	501	400	500	175	125	-
Electric Output (MWh)	633.8	838.8	1071.5	315.8	521.7	140.8
Thermal Displ. (MMBTU)	268.25	389.75	406.38	27.88	22.75	0.00
Fuel Input (MMBTU)	6683.6	8589.4	11426.7	3521.7	5744.5	1559.6
Average Energy Rates						
Demand Rate ($/kW):	-	-	-	-	-	-
Electric Rate ($/kWh):	0.0700	0.0800	0.0900	0.1022	0.1017	0.1017
Facility Gas Rate ($/MMBTU):	5.00	5.00	5.00	5.11	4.08	4.08
Generator Gas Rate ($/MMBTU):	5.00	5.00	5.00	5.11	4.08	4.08
GENERATOR SAVINGS						
Energy Savings ($):						
Demand:	-	-	-	-	-	-
Energy:	$44,366	$67,104	$96,435	$32,275	$53,057	$14,319
Displaced Fuel:	$1,341	$1,949	$2,032	$142	$93	$0
Subtotal ($):	***$45,707***	***$69,053***	***$98,467***	***$32,417***	***$53,150***	***$14,319***
Costs ($):						
Fuel Cost:	$33,418	$42,947	$57,134	$18,003	$23,415	$6,357
Maintenance:	$2,222	$53,823	$27,428	$28,485	$26,470	$7,029
Generator Overhaul:	$0	$0	$0	$0	$0	$0
Subtotal ($):	***$35,640***	***$96,770***	***$84,562***	***$46,488***	***$49,885***	***$13,386***
Annual Savings:	$10,067	($27,717)	$13,905	($14,071)	$3,265	$933
Cumulative Savings:	$10,067	($17,650)	($3,745)	($17,815)	($14,550)	($13,617)
Installed Cost	**$1,200,000**					
Net Cash Flow	**($1,189,933)**	**($27,717)**	**$13,905**	**($14,071)**	**$3,265**	**$933**
Cumulative Cash Flow	**($1,189,933)**	**($1,217,650)**	**($1,203,745)**	**($1,217,815)**	**($1,214,550)**	**($1,213,617)**

6 Summary, Conclusions, and Recommendations

6.1 Review of Fuel Cell Demonstration at MCAGCC Twentynine Palms

The 200 kW phosphoric acid fuel cell operated for 21,890 hours which corresponds to an availability of 50.8 percent. The fuel cell generated approximately 3,522 MWh of electricity at an average rate of 160.9 kW. The fuel cell electrical efficiency averaged 32.0 percent (HHV) over the course of the demonstration. The thermal utilization of 40,600 BTU/hr was only 6 percent of the fuel cell's capability of 700,000 BTU/hr. Data in Table 32 summarize the performance of the fuel cell operation.

Table 32. Summary of fuel cell performance.

	1995	1996	1997	1998	1999	2000	Totals
Fuel Cell Operation							
Hours in the Period	4,664.2	8,784.0	8,760.0	8,760.0	8,760.0	3,366.0	**43,094.2**
Fuel Cell Operation Hours	3,705.3	4,836.4	5,970.3	1,989.3	4,253.3	1,135.8	**21,890.5**
Fuel Cell Outage Hours	958.9	3,947.6	2,789.7	6,770.7	4,506.7	2,230.2	**21,203.7**
Availability	79.4%	55.1%	68.2%	22.7%	48.6%	33.7%	**50.8%**
Electric Generation							
Total Generation (MWh)	633.8	838.8	1,071.5	315.8	521.7	140.8	**3,522.5**
Average Rate of Generation (kW)	171.1	173.4	179.5	158.8	122.7	124.0	**160.9**
Natural Gas Consumption							
Total Consumption (Ft^3)	6,488,973.3	8,339,251.1	11,093,926.4	3,419,098.2	5,577,173.3	1,514,140.0	**36,432,562.3**
Average Rate of Consumption Ft^3/hr)	1,751.3	1,724.3	1,858.2	1,718.7	1,311.3	1,333.1	**1,664.3**
Heat Recovery							
Total Heat Recovered (MMBTU)	214.64	311.81	325.11	22.26	18.21	0.00	**892.0**
Average Rate of Recovery (kBTU/Hr)	57.93	64.47	54.45	11.19	4.28	0.00	**40.75**
Efficiencies							
Electrical (%)	32.4%	33.3%	32.0%	30.6%	31.0%	30.8%	**32.0%**
PURPA (%)	34.0%	35.1%	33.4%	30.9%	31.2%	30.8%	**33.2%**

The longest continuous period of operation was just under 2,100 hours, or about 3 months and the longest forced outage was 2,260 hours, or about 3 months. The fuel cell stack had to be replaced once during the demonstration period and an external water treatment system had to be retrofit to the fuel cell due to high conductivity of the water. A total of 36 outages were recorded with 33 outages classified as a forced outage.

At the completion of the demonstration, the fuel cell was not functional and the Base opted not to invest its own money in repairing, operating and maintaining the fuel cell. In accordance with the demonstration agreement, the fuel cell was removed at the request of the Base.

6.2 Lessons Learned

The experience of installing, operating and finally decommissioning the fuel cell, resulted in the following lessons learned:

- High conductivity of water, particularly due to the hardness of the water in the Southwest region of the United States, must be addressed to prevent negatively impacting the performance of the fuel cell stack.
- Installation of the fuel cell was a relatively straight forward process with no major concerns at this site. The installation took 3½ months.
- The level of energy savings was less than anticipated due to:
    - the average fuel cell electrical output, which was only 161 kW and not the anticipated 200 kW.
    - the fuel cell availability, which was only 50.8%, not the anticipated 95%.
    - the level of heat recovery, which averaged approximately 6% instead of the anticipated 60%.
    - the fuel cell's potential to reduce the demand of the Hospital in only 10 of the 59 months of the demonstration.
- Most of the forced outages were categorized as "Other," which accounted for a total of 7,852 hours, or 48% of the forced outage down time.
- The average duration of a forced outage was 497.6 hours, or approximately 21 days.
- The maintenance costs averaged $29,100/year, which represents an average cost of 4.12 cents/kWh. This does not include the equipment cost of the replacement cell stack or the reverse osmosis unit.
- The average fuel cost to generate electricity was 5.2 cents/kWh ($181,273 / 3,522,500 kWh).
- The average operating and maintenance costs to generate electricity was 9.3 cents/kWh (5.2 cents/kWh [fuel cost] + 4.12 cents/kWh [O&M costs]). Note that this does not include the value of the heat recovered from the fuel cell. Over the same period of time, the cost of electricity purchased from SCE averaged 9.2 cents/kWh.

6.3 Recommendations

The review and analysis of the 200 kW phosphoric acid fuel cell installed at MCAGCC Twentynine Palms resulted in several recommendations:

- ***Water Quality Requirements***. UTC Fuel Cells has identified through the demonstration that the hardness of the water impacts the fuel cell operation. The Twentynine Palms fuel cell required the installation of a reverse osmosis water treatment system. It is recommended that further research be done to determine the hardness level at which the fuel cell will require an RO system

- ***Fuel Cell Electrical Efficiency Trends.*** The analysis of the electrical efficiency trends showed that, in addition to the number of load hours, other factors affect the efficiency degradation. The secondary analysis that was conducted based on evaluating the trends between major system changes did not substantially improve on the ability to better quantify the electrical efficiency degradation. It is recommended that further evaluation be done to qualify the trends of other demonstration fuel cells might provide more insight.
- ***Cell Voltage Trends.*** The analysis of the cell voltage trends showed that the rate of cell voltage reduction was greater at the higher electric output levels (200 kW and 175 kW) than at lower electric output levels (125 kW and 150 kW) as the fuel cell load hours increase. It is recommended that these trends be further analyzed to see if this consistent with other fuel cells.
- ***System Design Improvements***. As part of the fuel cell demonstration and overall fuel cell development, UTC Fuel Cells refined the fuel cell design based on operational experience gained through the operation of the fleet of fuel cells. These improvements and modifications were classified as retrofits. The details of the retrofits are considered proprietary information by UTC Fuel Cells and are not available for this report. Investigation of maintenance activities for a larger number of B type fuel cells is recommended to provide greater insight into the modifications to the fuel cell design that can be attributed to the demonstration program.

Appendix A: Fuel Cell Acceptance Test Report

ONSI CORPORATION

ON SITE ACCEPTANCE TEST REPORT

POWER PLANT:	S/N 9061
LOCATION:	NAVAL HOSPITAL MCAGCC TWENTY NINE PALMS, CALIFORNIA
TEST DATES:	JUNE 16 THROUGH JUNE 21, 1995

ONSI CORPORATION

01/23/95

DoD ACCEPTANCE TEST OF PC25™ POWER PLANT INSTALLATION

- Following a normal power plant start-up, operate at IDLE for one hour. At the completion of the one hour, obtain prints of the following five (5) display screens.

-	KEY PARAMETERS	(screen 09)
-	REACTANT SUPPLY SYSTEM	(screen 10)
-	STACK LOOP, ANC LOOP, & WTS	(screen 11)
-	ELECTRICAL OVERVIEW	(screen 14)
-	POWER CONDITIONER SYSTEM	(screen 25)

- In the grid connect mode with unity power factor and no heat recovery, operate at each of the following powers for one hour. After one hour obtain prints of the five (5) screen displays outlined above. Also perform the additional demonstrations at 100 KW and 200 KW listed below which are accomplished after the one hour hold. The required display screen prints for verification are shown in brackets {}.

  * 50 KW
  * 100 KW
    - demonstrate leading and lagging power factor for 5 minutes
      - max leading power factor up to 0.85 within limitiations imposed by the grid {screen 14}
      - 0.85 lagging power factor {screen 14}
  * 150 KW
  * 200 KW (Rated Power)
    - demonstrate < 3% harmonic distortion [using THD meter across the output power breaker)
    - demonstrate 60 Hz ± 3 Hz frequency [using a Fluke Model 87 True RMS Multimeter or equivalent]
    - demonstrate leading and lagging power factors for 5 minutes
      - max leading power factor up to 0.85 within limitiations imposed by the grid {screen 14}
      - 0.85 lagging power factor {screen 14}
    - demonstrate minimum of 2 hours of heat recovery at time of normal site heat usage and consistent with site design
      - {screen 09 at beginning and end of demonstration plus screen 11 at beginning and every hour until heat recovery demonstration completed}
      - confirmation of 1900 SCFH ± 100 SCFH natural gas consumption during this two hour hold

- Grid Independent operation will be demonstrated at those sites where such capability is installed, at power conditions consistent with normal site demand. After one hour of grid independent operation, each of the five (5) screens displays noted above shall be printed as verification.
    - demonstrate 60 Hz ± 3 Hz frequency [using a Fluke Model 87 True RMS Multimeter or equivalent]
    - demonstrate 480 volts ± 3%

```
                          STACK LOOP, ANC LOOP, & WTS
06/16/95  IDC=    239.2  VDC= 237  KWACNET=     2  VT310DEL= -0.91  EVENTS  0
0656:41   FT012ACT=  21.2  TE400FT= 370.1  TE012FT=   1495        OVERRIDE  0
P/P  9061 P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 26

TE400     SEPARATOR TEMP (PRIMARY) 370.2  DEGF  SETPOINT:                370.0
TE400R    SEPARATOR TEMP (BACKUP)  369.8  DEGF  SEP TEMP FACTOR(DEGF)      1.0
TE400DEL  SEP TEMP DELTA             0.4  DEGF
LS450     WATER TANK LEVEL SWITCH    On         STK FLOW SW (FS400)        On
TE431     POLISHER TEMP             75.7  DEGF  F/W TEMP SW (TS451)        On
TE810     CONDENSOR EXIT TEMP      138.8  DEGF
TE820     CUST HEX HOT IN TEMP     153.3  DEGF  CUMHEATREC(MMBTU)       0.689
TE880     CUST HEX COLD IN TEMP     90.0  DEGF  FT880 FLOW (PPH)        21940
TE881     CUST HEX COLD EX TEMP    102.3  DEGF  HEAT REC (MBTU/HR)        270
TE401     STACK COOLANT INLET TEMP 361.2  DEGF
LT400     SEPARATOR LEVEL           11.2  IN

PMP451    WTS FEEDWATER PUMP         Off        ON TIME, MIN.(FWPUMP):      0
STARTTEMP TEMP FOR REF HEATUP      350.0  DEGF
IDCNET    NET DC CURRENT           -42.6  AMPS

HTR400    ELEMENT "A"                On         ELEMENT "C"                On
          ELEMENT "B"                On         ELEMENT "D"                Off
```

```
                    KEY PARAMETERS (ENGLISH UNITS)
P/P  9061    06/16/95     0653:33          EVENTS:   0          OVERRIDE:   0
P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 26
POWER OUTPUT (NET)          2.5  KWAC   OPERATING TIME           66.7  HRS
POWER OUTPUT (GROSS)       56.3  KWAC   POWER FACTOR             0.90
STACK CURRENT             239.1  AMPS   CUMULATIVE POWER        0.839  MWHR
STACK VOLTAGE             237.4  VOLTS  HALF STACK VOLTAGE      -0.09  VOLTS
VOLUMETRIC FUEL FLOW      461.2  SCFH   FUEL FLOW SETPOINT      457.6  SCFH
ACTUAL FUEL FLOW           20.7  PPH
ZT010 EJECTOR POSITION     18.9  %      ZT010 SETPOINT           19.1  %
PHI MONITOR                1.02         TOTAL FUEL CONS         32622  SCF
FT140 BURNER AIR FLOW     206.7  PPH    FT140 SETPOINT          210.0  PPH
TE012 REFORMER TEMP      1492.7  DEGF   ZT110 POSITION           41.9  %
TE012R BACKUP REF TEMP   1486.1  DEGF   TE012 SETPOINT         1495.0  DEGF

TE002 HDS TEMP            499.7  DEGF   TE350 ANODE INLET TEMP 395.6  DEGF

TE400FT STEAM SEP TEMP    371.9  DEGF   TE400 SETPOINT          370.0  DEGF
TE881 TEMP TO CUST        102.3  DEGF   RECOVERED HEAT            289  MBTU/HR
                                        TE431 POLISHER TEMP      75.7  DEGF
LT400 SEPARATOR LEVEL      10.5  IN     TE810 GLYCOL TEMP       140.8  DEGF
PMP451 STATUS               Off         TE160 MOTOR COMP AIR     68.7  DEGF
                                        TE150 MOT COMP AIR IN    62.7  DEGF
ELECTRICAL EFFICIENCY       2.0  %      press <NEXT PAGE> key to view RM data
```

```
                         REACTANT SUPPLY SYSTEM
06/16/95  IDC=   243.5  VDC= 237  KWACNET=     2   VT310DEL= -0.91  EVENTS  0
0655:38   FT012ACT=  21.4  TE400FT=  370  TE012FT=  1494          OVERRIDE  0
P/P  9061 P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 26

TE012     REF TUBE TEMP (PRIMARY) 1494.4  DEGF  SETPOINT:              1497.3
TE012R    REF TUBE TEMP (BACKUP)  1487.4  DEGF  REF/FUEL CONT OUTPUT:    1.13
TE012DEL  REF TUBE TEMP DELTA        7.0  DEGF
FT012ACT  ACTUAL MASS FUEL FLOW     21.4  PPH   SETPOINT:                21.0
FT012     UNCORR. MASS FUEL FLOW    22.6  PPH   TE013 FUEL TEMP(DEGF)    56.9
SCFH      ACTUAL VOLUME FUEL FLOW  475.9  CFH   SETPOINT:               468.0
FUELTOT   TOTAL FUEL CONSUMED      22637  SCF   PT012 VENTURI(PSIA)      7.88

ZT010     EJECTOR POSITION          19.0  %     SETPOINT:                18.3
PHIMON    PHI MONITOR               1.02        STEAM FLOW S.P.(PPH):   105.0
TE350     ANODE INLET TEMP         397.5  DEGF


TE002     HDS BED TEMP             499.3  DEGF  HTR002 STATUS:             On


EFFREF   REFORMER EFFICIENCY        77.6  %
```

```
                          ELECTRICAL OVERVIEW
06/16/95  IDC=    239  VDC= 237  KWACNET=     2.5   VT310DEL= -0.91  EVENTS  0
0657:53   FT012ACT=  21.1  TE400FT=  369  TE012FT=  1498       OVERRIDES   0
P/P  9061 P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 26

LOADTIME  TOTAL LOAD TIME               66   HR
HOTTIME   TOTAL HOT TIME               120   HR
CELV      AVG VOLTS PER CELL          .741   V/C
ASF       CURRENT DENSITY               42   ASF
KWDC      DC KILOWATTS                56.7   KW
VT310DEL  DELTA HALF STK VOLT        -0.91   V     VT310 HALF STK VOLT    -0.08
          INSTANTANEOUS STK AMPS       239   A
EFFINV    INVERTER EFFICIENCY         99.3   %     CELL EFFICIENCY (%)     59.3
EFFMECH   MECHANICAL EFFICIENCY        4.4   %     REF EFFICIENCY (%)      75.5
EFFELEC   ELECTRICAL EFFICIENCY        1.9   %     HEAT RATE (BTU/KWHR)  190563

KWACNET   NET AC POWER                 2.5   KWAC  DISPATCHED POWER:        0.0
PFACT     ACTUAL POWER FACTOR         0.90   -     DISPATCHED P.F.:        1.00
KVARNET   NET KVAR                     1.1   KVAR  DISPATCHED KVAR:         0.0
KVANET    NET KVA                      2.7   KVA
PARPOWER  PARASITE POWER              53.7   KW
KWACGROS  GROSS AC POWER              56.3   KW
MWHRSGR   GROSS AC MW HRS            2.369   MWHR
MWHRSNET  NET AC MW HOURS            0.840   MWHR
```

```
                              POWER CONDITIONER SYSTEM
06/16/95   IDC=  239   VDC= 237      KWACNET=   2.5  VT310DEL= -0.92  EVENTS  0
0658:49    FT012ACT=  21.1  TE400FT= 370.0  TE012FT= 1500.6        OVERRIDE  0
P/P  9061 P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 26

PT001A     INV AC VOLTAGE,PHASE A    483.7  V
PT001B     INV AC VOLTAGE,PHASE B    480.6  V
PT001C     INV AC VOLTAGE,PHASE C    476.5  V
CT001A     INV AC CURRENT,PHASE A      0.5  A
CT001B     INV AC CURRENT,PHASE B      0.0  A
CT001C     INV AC CURRENT,PHASE C      0.1  A   CURRENT UNBAL (%)        0.0

PT003A     NET AC VOLTAGE,PHASE A    494.5  V
PT003B     NET AC VOLTAGE,PHASE B    492.0  V
PT003C     NET AC VOLTAGE,PHASE C    489.2  V   VOLTAGE UNBAL (%)        1.0
LINKVDC    LINK VOLTAGE              600.3  V

PERCFUND   PERCENT FUNDAMENTAL        83.8  %
PSREQ      PHASE SHIFT REQUEST         2.0  DEG
MCB001     G/I BREAKER STATUS         Off
MCB002     G/C BREAKER STATUS         Off
MCB003     INTER-TIE BREAKER STAT     On
INTCOUNT   INTERRUPT COUNT              0
```

```
                      KEY PARAMETERS (ENGLISH UNITS)
P/P  9061    06/16/95     0837:02         EVENTS:   0          OVERRIDE:   0
P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50
POWER OUTPUT (NET)          50.7  KWAC   OPERATING TIME          68.4  HRS
POWER OUTPUT (GROSS)       102.9  KWAC   POWER FACTOR           -1.00
STACK CURRENT              459.8  AMPS   CUMULATIVE POWER       0.915  MWHR
STACK VOLTAGE              223.0  VOLTS  HALF STACK VOLTAGE      0.05  VOLTS
VOLUMETRIC FUEL FLOW       900.9  SCFH   FUEL FLOW SETPOINT     850.7  SCFH
ACTUAL FUEL FLOW            40.5  PPH
ZT010 EJECTOR POSITION      24.7  %      ZT010 SETPOINT          23.7  %
PHI MONITOR                 0.98         TOTAL FUEL CONS        24035  SCF
FT140 BURNER AIR FLOW      282.3  PPH    FT140 SETPOINT         283.1  PPH
TE012 REFORMER TEMP       1523.6  DEGF   ZT110 POSITION          45.7  %
TE012R BACKUP REF TEMP    1522.1  DEGF   TE012 SETPOINT        1514.4  DEGF

TE002 HDS TEMP             500.1  DEGF   TE350 ANODE INLET TEMP 395.4  DEGF

TE400FT STEAM SEP TEMP     357.7  DEGF   TE400 SETPOINT         360.6  DEGF
TE881 TEMP TO CUST         129.8  DEGF   RECOVERED HEAT             0  MBTU/HR
                                         TE421 POLISHER TEMP     74.8  DEGF
LT400 SEPARATOR LEVEL       11.4  IN     TE810 GLYCOL TEMP      139.3  DEGF
PMP451 STATUS                Off         TE150 MOTOR COMP AIR    64.9  DEGF
                                         TE150 MOT COMP AIR IN   67.6  DEGF
ELECTRICAL EFFICIENCY       20.5  %      press <NEXT PAGE> key to view RM data
```

```
                        REACTANT SUPPLY SYSTEM
06/16/95  IDC=   457.6  VDC= 226  KWACNET=   48   VT310DEL= -0.58  EVENTS  0
0839:24   FT012ACT=  38.3  TE400FT=  358  TE012FT=  1524          OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE012     REF TUBE TEMP (PRIMARY) 1524.3  DEGF  SETPOINT:                1514.4
TE012R    REF TUBE TEMP (BACKUP)  1522.5  DEGF  REF/FUEL CONT OUTPUT:    1.06
TE012DEL  REF TUBE TEMP DELTA        1.7  DEGF
FT012ACT  ACTUAL MASS FUEL FLOW     38.3  PPH   SETPOINT:                37.0
FT012     UNCORR. MASS FUEL FLOW    42.0  PPH   TE011 FUEL TEMP(DEGF)    71.1
SCFH      ACTUAL VOLUME FUEL FLOW  851.7  CFH   SETPOINT:               900.4
FUELTOT   TOTAL FUEL CONSUMED      34064  SCF   PT012 VENTURI(PSIA)      7.29

ZT010     EJECTOR POSITION          24.5  %     SETPOINT:                23.3
PHIMON    PHI MONITOR               1.13        STEAM FLOW S.P.(PPH):   143.8
TE350     ANODE INLET TEMP         396.6  DEGF


TE002     HDS BED TEMP             500.1  DEGF  HTR002 STATUS:             On


EFFREF   REFORMER EFFICIENCY        80.7  %



                        STACK LOOP, ANC LOOP, & WTS
06/16/95  IDC=   459.9  VDC= 223  KWACNET=    49  VT310DEL= -0.78  EVENTS  0
0849:06   FT012ACT=  41.2  TE400FT= 359.9  TE012FT=  1511        OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE400     SEPARATOR TEMP (PRIMARY) 359.9  DEGF  SETPOINT:              358.3
TE400R    SEPARATOR TEMP (BACKUP)  359.5  DEGF  SEP TEMP FACTOR(DEGF)    1.0
TE400DEL  SEP TEMP DELTA             0.4  DEGF
LS450     WATER TANK LEVEL SWITCH     On        STK FLOW SW (FS400)      On
TE431     POLISHER TEMP             74.6  DEGF  F/W TEMP SW (TS451)      On
TE810     CONDENSOR EXIT TEMP      139.9  DEGF
TE820     CUST HEX HOT IN TEMP     173.8  DEGF  CUMHEATREC(MMBTU)      1.056
TE880     CUST HEX COLD IN TEMP    172.9  DEGF  FT880 FLOW (PPH)          0
TE881     CUST HEX COLD EX TEMP    123.6  DEGF  HEAT REC (MBTU/HR)     0  0
TE401     STACK COOLANT INLET TEMP 339.0  DEGF
LT400     SEPARATOR LEVEL           11.2  IN

PMP451    WTS FEEDWATER PUMP         Off        ON TIME, MIN.(FWPUMP):    0
STARTTEMP TEMP FOR REF HEATUP      350.0  DEGF
IDCNET    NET DC CURRENT           224.3  AMPS

HTR400    ELEMENT "A"                Off        ELEMENT "C"              On
          ELEMENT "B"                On         ELEMENT "D"              Off
```

```
                          ELECTRICAL OVERVIEW
06/15/95  IDC=   473  VDC= 224  KWACNET=   50.2  VT310DEL= -0.85  EVENTS   0
0845:35   FT012ACT=  37.7  TE400FT=  362  TE012FT=  1507          OVERRIDES  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME              68  HR
HOTTIME   TOTAL HOT TIME              122  HR
CELV      AVG VOLTS PER CELL         .700  V/C
ASF       CURRENT DENSITY              84  ASF
KWDC      DC KILOWATTS              106.2  KW
VT310DEL  DELTA HALF STK VOLT       -0.85  V     VT310 HALF STK VOLT     -0.01
          INSTANTANEOUS STK AMPS      465  A
EFFINV    INVERTER EFFICIENCY        99.0  %     CELL EFFICIENCY (%)      56.0
EFFMECH   MECHANICAL EFFICIENCY      48.0  %     REF EFFICIENCY (%)       86.6
EFFELEC   ELECTRICAL EFFICIENCY      23.0  %     HEAT RATE (BTU/KWHR)    16506

KWACNET   NET AC POWER               50.2  KWAC  DISPATCHED POWER:        50.0
PFACT     ACTUAL POWER FACTOR       -1.00  -     DISPATCHED P.F.:         1.00
KVARNET   NET KVAR                   -1.1  KVAR  DISPATCHED KVAR:          0.0
KVANET    NET KVA                    49.7  KVA
PARPOWER  PARASITE POWER             55.0  KW
KWACGROS  GROSS AC POWER            105.2  KW
MWHRSGR   GROSS AC MW HRS           2.549  MWHR
MWHRSNET  NET AC MW HOURS           0.922  MWHR
```

```
                           POWER CONDITIONER SYSTEM
06/16/95  IDC=  462  VDC= 224    KWACNET=  49.9  VT310DEL= -0.80  EVENTS  0
0846:35   FT012ACT=  40.4  TE400FT= 361.5  TE012FT= 1511.1        OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

PT001A    INV AC VOLTAGE,PHASE A   497.5  V
PT001B    INV AC VOLTAGE,PHASE B   494.2  V
PT001C    INV AC VOLTAGE,PHASE C   493.2  V
CT001A    INV AC CURRENT,PHASE A    53.7  A
CT001B    INV AC CURRENT,PHASE B    56.9  A
CT001C    INV AC CURRENT,PHASE C    58.2  A   CURRENT UNBAL (%)       7.5

PT003A    NET AC VOLTAGE,PHASE A   497.6  V
PT003B    NET AC VOLTAGE,PHASE B   495.2  V
PT003C    NET AC VOLTAGE,PHASE C   492.3  V   VOLTAGE UNBAL (%)       1.0
LINKVDC   LINK VOLTAGE             599.7  V

PERCFUND  PERCENT FUNDAMENTAL       86.5  %
PSREQ     PHASE SHIFT REQUEST        4.8  DEG
MCB001    G/I BREAKER STATUS         Off
MCB002    G/C BREAKER STATUS         On
MCB003    INTER-TIE BREAKER STAT     On
INTCOUNT  INTERRUPT COUNT              0
```

```
                         KEY PARAMETERS (ENGLISH UNITS)
P/P  9061     06/16/95      1027:37            EVENTS:    0           OVERRIDE:    0
F 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50
POWER OUTPUT (NET)           101.0  KWAC  OPERATING TIME          70.3  HRS
POWER OUTPUT (GROSS)         117.7  KWAC  POWER FACTOR            0.99
STACK CURRENT                539.5  AMPS  CUMULATIVE POWER       1.084  MWHR
STACK VOLTAGE                220.9  VOLTS HALF STACK VOLTAGE      0.03  VOLTS
VOLUMETRIC FUEL FLOW         993.2  SCFH  FUEL FLOW SETPOINT    1002.5  SCFH
ACTUAL FUEL FLOW              44.7  PPH
ZT010 EJECTOR POSITION        26.9  %     ZT010 SETPOINT          25.9  %
PHI MONITOR                   1.05        TOTAL FUEL CONS        35819  SCF
FT140 BURNER AIR FLOW        315.1  PPH   FT140 SETPOINT         319.3  PPH
TE012 REFORMER TEMP         1521.2  DEGF  ZT110 POSITION          48.7  %
TE012R BACKUP REF TEMP      1519.0  DEGF  TE012 SETPOINT        1520.5  DEGF

TE002 HDS TEMP               510.7  DEGF  TE350 ANODE INLET TEMP 397.3  DEGF

TE400FT STEAM SEP TEMP       355.8  DEGF  TE400 SETPOINT         356.8  DEGF
TE881 TEMP TO CUST           102.5  DEGF  RECOVERED HEAT          0  0  MBTU/HR
                                          TE431 POLISHER TEMP     82.3  DEGF
LT400 SEPARATOR LEVEL         11.1  IN    TE810 GLYCOL TEMP      140.6  DEGF
PMP451 STATUS                  Off        TE160 MOTOR COMP AIR    74.4  DEGF
                                          TE150 MOT COMP AIR IN   69.8  DEGF
ELECTRICAL EFFICIENCY         37.3  %     press <NEXT PAGE> key to view RM data
```

```
                          REACTANT SUPPLY SYSTEM
06/16/95  IDC=   521.3  VDC= 222  KWACNET=   101   VT310DEL= -0.80  EVENTS  0
1028:43   FT012ACT=  44.4  TE400FT=   357  TE012FT=  1522          OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE012      REF TUBE TEMP (PRIMARY) 1522.1  DEGF  SETPOINT:                1519.6
TE012R     REF TUBE TEMP (BACKUP)  1520.4  DEGF  REF/FUEL CONT OUTPUT:      1.09
TE012DEL   REF TUBE TEMP DELTA        1.7  DEGF
FT012ACT   ACTUAL MASS FUEL FLOW     44.4  PPH   SETPOINT:                  43.5
FT012      UNCORR. MASS FUEL FLOW    50.7  PPH   TE011 FUEL TEMP(DEGF)      75.0
SCFH       ACTUAL VOLUME FUEL FLOW  986.9  CFH   SETPOINT:                 957.6
FUELTOT    TOTAL FUEL CONSUMED      35836  SCF   PT012 VENTURI(PSIA)        6.85

ZT010      EJECTOR POSITION          26.3  %     SETPOINT:                  25.3
PHIMON     PHI MONITOR               1.02        STEAM FLOW S.P.(PPH):     161.8
TE350      ANODE INLET TEMP         398.2  DEGF


TE002      HDS BED TEMP             510.2  DEGF  HTR002 STATUS:               On


EFFREF     REFORMER EFFICIENCY       78.9  %
```

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                        STACK LOOP, ANC LOOP, & WTS
06/16/95  IDC=   542.1  VDC= 221  KWACNET=     99  VT310DEL= -0.81  EVENTS  0
1029:49   FT012ACT=  44.6  TE400FT= 356.9  TE012FT=   1524          OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE400     SEPARATOR TEMP (PRIMARY) 357.3  DEGF  SETPOINT:                  356.7
TE400R    SEPARATOR TEMP (BACKUP)  357.3  DEGF  SEP TEMP FACTOR(DEGF)        1.0
TE400DEL  SEP TEMP DELTA             0.0  DEGF
LS450     WATER TANK LEVEL SWITCH     On        STK FLOW SW (FS400)          On
TE431     POLISHER TEMP             81.6  DEGF  F/W TEMP SW (TS451)          On
TE810     CONDENSOR EXIT TEMP      139.9  DEGF
TE820     CUST HEX HOT IN TEMP     160.6  DEGF  CUMHEATREC(MMBTU)         1.055
TE880     CUST HEX COLD IN TEMP    150.0  DEGF  FT880 FLOW (PPH)              0
TE681     CUST HEX COLD EX TEMP    103.4  DEGF  HEAT REC (MBTU/HR)        0   0
TE401     STACK COOLANT INLET TEMP 329.1  DEGF
LT400     SEPARATOR LEVEL           10.8  IN

PMP451    WTS FEEDWATER PUMP          On        ON TIME, MIN.(FWPUMP):        0
STARTTEMP TEMP FOR REF HEATUP      350.0  DEGF
IDCNET    NET DC CURRENT           544.5  AMPS

HTR400    ELEMENT "A"                Off        ELEMENT "C"                 Off
          ELEMENT "B"                Off        ELEMENT "D"                 Off
```

```
                          ELECTRICAL OVERVIEW
06/16/95  IDC=   535  VDC= 222  KWACNET=   99.1  VT310DEL= -0.84  EVENTS  0
1031:21   FT012ACT=  44.4  TE400FT=  356  TE012FT=  1524         OVERRIDES  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME               70   HR
HOTTIME   TOTAL HOT TIME               123   HR
CELV      AVG VOLTS PER CELL          .695   V/C
ASF       CURRENT DENSITY               96   ASF
KWDC      DC KILOWATTS               119.3   KW
VT310DEL  DELTA HALF STK VOLT        -0.84   V     VT310 HALF STK VOLT     -0.01
          INSTANTANEOUS STK AMPS       539   A
EFFINV    INVERTER EFFICIENCY         98.0   %     CELL EFFICIENCY (%)      55.5
EFFMECH   MECHANICAL EFFICIENCY       86.9   %     REF EFFICIENCY (%)       79.6
EFFELEC   ELECTRICAL EFFICIENCY       37.5   %     HEAT RATE (BTU/KWHR)    10093

KWACNET   NET AC POWER               100.3   KWAC  DISPATCHED POWER:       100.0
PFACT     ACTUAL POWER FACTOR        -1.00   -     DISPATCHED P.F.:         1.00
KVARNET   NET KVAR                    -0.5   KVAR  DISPATCHED KVAR:          0.0
KVANET    NET KVA                    100.4   KVA
PARPOWER  PARASITE POWER              16.3   KW
KWACGROS  GROSS AC POWER             116.5   KW
MWHRSGR   GROSS AC MW HRS            2.754   MWHR
MWHRSNET  NET AC MW HOURS            1.091   MWHR
```

```
                              POWER CONDITIONER SYSTEM
06/16/95  IDC=  539  VDC= 221   KWACNET= 100.2  VT310DEL= -0.80  EVENTS  0
1032:46   FT012ACT=  44.5  TE400FT= 356.8  TE012FT= 1523.9      OVERRIDE  0
F/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

PT001A    INV AC VOLTAGE,PHASE A   492.8  V
PT001B    INV AC VOLTAGE,PHASE B   490.1  V
PT001C    INV AC VOLTAGE,PHASE C   490.5  V
CT001A    INV AC CURRENT,PHASE A   108.0  A
CT001B    INV AC CURRENT,PHASE B   126.2  A
CT001C    INV AC CURRENT,PHASE C   121.3  A   CURRENT UNBAL (%)       12.3

PT003A    NET AC VOLTAGE,PHASE A   493.1  V
PT003B    NET AC VOLTAGE,PHASE B   490.8  V
PT003C    NET AC VOLTAGE,PHASE C   488.4  V   VOLTAGE UNBAL (%)        1.0
LINKVDC   LINK VOLTAGE             599.8  V

PERCFUND  PERCENT FUNDAMENTAL       86.3  %
PSREQ     PHASE SHIFT REQUEST        6.5  DEG
MCB001    G/I BREAKER STATUS        Off
MCB002    G/C BREAKER STATUS        On
MCB003    INTER-TIE BREAKER STAT    On
INTCOUNT  INTERRUPT COUNT             0
```

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                         ELECTRICAL OVERVIEW
06/16/95  IDC=   546  VDC= 221  KWACNET=  100.1  VT310DEL= -0.80  EVENTS  0
1041:36   FT012ACT=  45.0  TE400FT=  356  TE012FT=  1529      OVERRIDES  0
F/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME            70  HR
HOTTIME   TOTAL HOT TIME            124  HR
CELV      AVG VOLTS PER CELL       .691  V/C
ASF       CURRENT DENSITY            98  ASF
KWDC      DC KILOWATTS            121.1  KW
VT310DEL  DELTA HALF STK VOLT     -0.80  V     VT310 HALF STK VOLT      0.02
          INSTANTANEOUS STK AMPS    542  A
EFFINV    INVERTER EFFICIENCY      97.9  %     CELL EFFICIENCY (%)      55.4
EFFMECH   MECHANICAL EFFICIENCY    84.5  %     REF EFFICIENCY (%)       77.5
EFFELEC   ELECTRICAL EFFICIENCY    35.5  %     HEAT RATE (BTU/KWHR)    10669

KWACNET   NET AC POWER            100.1  KWAC  DISPATCHED POWER:       100.0
PFACT     ACTUAL POWER FACTOR      0.90  -     DISPATCHED P.F.:         0.85
KVARNET   NET KVAR                 45.9  KVAR  DISPATCHED KVAR:         61.9
KVANET    NET KVA                 110.6  KVA
PARPOWER  PARASITE POWER           18.3  KW
KWACGROS  GROSS AC POWER          118.4  KW
MWHRSGR   GROSS AC MW HRS         2.773  MWHR
MWHRSNET  NET AC MW HOURS         1.107  MWHR
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```
                         ELECTRICAL OVERVIEW
05/16/95  IDC=   543  VDC= 221  KWACNET=  100.9   VT310DEL= -0.80  EVENTS  0
1051:11   FT012ACT=  45.6  TE400FT=  356  TE012PT=  1531        OVERRIDES  0
P/P  9061 F 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME              70  HR
HOTTIME   TOTAL HOT TIME              124  HR
CELV      AVG VOLTS PER CELL         .690  V/C
ASF       CURRENT DENSITY              97  ASF
KWDC      DC KILOWATTS              120.1  KW
VT310DEL  DELTA HALF STK VOLT       -0.80  V     VT310 HALF STK VOLT       0.02
          INSTANTANEOUS STK AMPS      544  A
EFFINV    INVERTER EFFICIENCY        97.7  %     CELL EFFICIENCY (%)       55.3
EFFMECH   MECHANICAL EFFICIENCY      85.9  %     REF EFFICIENCY (%)        78.5
EFFELEC   ELECTRICAL EFFICIENCY      36.3  %     HEAT RATE (BTU/KWHR)     10415

KWACNET   NET AC POWER              100.9  KWAC  DISPATCHED POWER:        100.0
PFACT     ACTUAL POWER FACTOR       -0.85  -     DISPATCHED P.F.:         -0.85
KVARNET   NET KVAR                  -59.0  KVAR  DISPATCHED KVAR:         -61.9
KVANET    NET KVA                   116.8  KVA
PARPOWER  PARASITE POWER             18.1  KW
KWACGROS  GROSS AC POWER            119.0  KW
MWHRSGR   GROSS AC MW HRS           2.793  MWHR
MWHRSNET  NET AC MW HOURS           1.124  MWHR
```

```
                    KEY PARAMETERS (ENGLISH UNITS)
P/P  9061    06/16/95    1201:57         EVENTS:   0          OVERRIDE:   0
F 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50
POWER OUTPUT (NET)        150.1  KWAC   OPERATING TIME          71.9  HRS
POWER OUTPUT (GROSS)      166.0  KWAC   POWER FACTOR           -1.00
STACK CURRENT             802.5  AMPS   CUMULATIVE POWER       1.295  MWHR
STACK VOLTAGE             212.1  VOLTS  HALF STACK VOLTAGE      0.16  VOLTS
VOLUMETRIC FUEL FLOW     1457.4  SCFH   FUEL FLOW SETPOINT    1456.7  SCFH
ACTUAL FUEL FLOW           65.6  PPH
ZT010 EJECTOR POSITION     43.2  %      ZT010 SETPOINT          42.1  %
PHI MONITOR                1.05         TOTAL FUEL CONS        37925  SCF
FT140 BURNER AIR FLOW     438.9  PPH    FT140 SETPOINT         435.2  PPH
TE012 REFORMER TEMP      1557.6  DEGF   ZT110 POSITION          63.1  %
TE012R BACKUP REF TEMP   1592.0  DEGF   TE012 SETPOINT        1556.6  DEGF

TE302 HDS TEMP            537.1  DEGF   TE350 ANODE INLET TEMP 399.5  DEGF

TE400FT STEAM SEP TEMP    349.1  DEGF   TE400 SETPOINT         348.4  DEGF
TE881 TEMP TO CUST         94.6  DEGF   RECOVERED HEAT           0.0  MBTU/HR
                                        TE431 POLISHER TEMP     86.5  DEGF
LT400 SEPARATOR LEVEL      11.3  IN     TE810 GLYCOL TEMP      155.5  DEGF
PMP451 STATUS               Off         TE160 MOTOR COMP AIR    74.2  DEGF
                                        TE150 MOT COMP AIR IN   73.5  DEGF
ELECTRICAL EFFICIENCY      38.5  %      press <NEXT PAGE> key to view RM data
```

```
                              REACTANT SUPPLY SYSTEM
06/16/95   IDC=   800.6   VDC= 212  KWACNET=   150   VT310DEL= -0.67   EVENTS  0
1203:45    FT012ACT=  66.5  TE400FT=  349   TE012FT=  1599            OVERRIDE  0
P/P  9061  P 160 R 160 S 60   W 20   A 30   N 40   C 30   L 10  I 50

TE012      REF TUBE TEMP (PRIMARY) 1599.9   DEGF   SETPOINT:                1597.1
TE012R     REF TUBE TEMP (BACKUP)  1605.6   DEGF   REF/FUEL CONT OUTPUT:     1.07
TE012DEL   REF TUBE TEMP DELTA        5.7   DEGF
FT012ACT   ACTUAL MASS FUEL FLOW     66.5   PPH    SETPOINT:                 65.6
FT012      UNCORR. MASS FUEL FLOW    71.1   PPH    TE011 FUEL TEMP(DEGF)     76.8
SCFH       ACTUAL VOLUME FUEL FLOW 1477.0   CFH    SETPOINT:               1460.1
FUELTOT    TOTAL FUEL CONSUMED      37950   SCF    PT012 VENTURI(PSIA)       7.85

ZT010      EJECTOR POSITION          42.1   %      SETPOINT:                 41.2
PHIMON     PHI MONITOR               1.01          STEAM FLOW S.P.(PPH):    242.2
TE350      ANODE INLET TEMP         399.3   DEGF


TS002      HDS BED TEMP             537.9   DEGF   HTR002 STATUS:             Off


EFFREF   REFORMER EFFICIENCY         80.6   %
```

```
                              STACK LOOP, ANC LOOP, & WTS
06/16/95   IDC=   806.7   VDC= 212  KWACNET=   151  VT310DEL= -0.67   EVENTS  0
1205:01    FT012ACT=  66.2  TE400FT= 349.0  TE012FT=   1606          OVERRIDE  0
P/P  9061  P 160  R 160  S 60   W 20   A 30   N 40   C 30   L 10  I 50

TE400      SEPARATOR TEMP (PRIMARY) 349.6   DEGF   SETPOINT:               348.5
TE400R     SEPARATOR TEMP (BACKUP)  348.7   DEGF   SEP TEMP FACTOR(DEGF)     0.9
TE400DEL   SEP TEMP DELTA             0.6   DEGF
LS450      WATER TANK LEVEL SWITCH    On           STK FLOW SW (FS400)       On
TE431      POLISHER TEMP             84.5   DEGF   F/W TEMP SW (TS451)       On
TE810      CONDENSOR EXIT TEMP      157.5   DEGF
TE820      CUST HEX HOT IN TEMP     189.8   DEGF   CUMHEATREC(MMBTU)       1.055
TE880      CUST HEX COLD IN TEMP    156.8   DEGF   FT880 FLOW (PPH)            0
TE881      CUST HEX COLD EX TEMP     95.0   DEGF   HEAT REC (MBTU/HR)        0.0
TE401      STACK COOLANT INLET TEMP 308.0   DEGF
LT400      SEPARATOR LEVEL           10.8   IN

PMP451     WTS FEEDWATER PUMP         On           ON TIME, MIN.(FWPUMP):      0
STARTTEMP  TEMP FOR REF HEATUP      350.0   DEGF
IDCNET     NET DC CURRENT           809.4   AMPS

HTR400     ELEMENT "A"               Off           ELEMENT "C"               Off
           ELEMENT "B"               Off           ELEMENT "D"               Off
```

```
                              ELECTRICAL OVERVIEW
06/15/95  IDC=   797  VDC= 212  KWACNET=  148.6   VT310DEL= -0.65  EVENTS  0
1206:00   PTC12ACT=  64.1  TE400FT=  350  TE012FT=  1607          OVERRIDES  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME              71   HR
HOTTIME   TOTAL HOT TIME              125   HR
CELV      AVG VOLTS PER CELL         .664   V/C
ASF       CURRENT DENSITY             142   ASF
KWDC      DC KILOWATTS              168.9   KW
VT310DEL  DELTA HALF STK VOLT       -0.65   V     VT310 HALF STK VOLT        0.18
          INSTANTANEOUS STK AMPS      802   A
EFFINV    INVERTER EFFICIENCY        97.6   %     CELL EFFICIENCY (%)        53.1
EFFMECH   MECHANICAL EFFICIENCY      90.1   %     REF EFFICIENCY (%)         82.0
EFFELEC   ELECTRICAL EFFICIENCY      38.2   %     HEAT RATE (BTU/KWHR)       9919

KWACNET   NET AC POWER              148.8   KWAC  DISPATCHED POWER:         150.0
PFACT     ACTUAL POWER FACTOR       -1.00   -     DISPATCHED P.F.:           1.00
KVARNET   NET KVAR                   -1.3   KVAR  DISPATCHED KVAR:            0.0
KVANET    NET KVA                   149.3   KVA
PARPOWER  PARASITE POWER             15.8   KW
KWACGROS  GROSS AC POWER            164.7   KW
MWHRSGR   GROSS AC MW HRS           2.996   MWHR
MWHRSNET  NET AC MW HOURS           1.307   MWHR


                              POWER CONDITIONER SYSTEM
06/15/95  IDC=  801  VDC= 212    KWACNET= 150.1  VT310DEL= -0.65  EVENTS  0
1206:59   PT012ACT=  64.0  TE400FT= 348.6  TE012FT= 1599.5        OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 20  N 40  C 30  L 10  I 50

PT001A    INV AC VOLTAGE,PHASE A    498.2  V
PT001B    INV AC VOLTAGE,PHASE B    496.3  V
PT001C    INV AC VOLTAGE,PHASE C    496.5  V
CT001A    INV AC CURRENT,PHASE A    164.0  A
CT001B    INV AC CURRENT,PHASE B    176.0  A
CT001C    INV AC CURRENT,PHASE C    179.5  A    CURRENT UNBAL (%)         9.1

PT003A    NET AC VOLTAGE,PHASE A    497.1  V
PT003B    NET AC VOLTAGE,PHASE B    495.8  V
PT003C    NET AC VOLTAGE,PHASE C    491.9  V    VOLTAGE UNBAL (%)         1.0
LINKVDC   LINK VOLTAGE              539.6  V

PERCFUND  PERCENT FUNDAMENTAL        88.8  %
PSREQ     PHASE SHIFT REQUEST         6.9  DEG
MCB001    G/I BREAKER STATUS         Off
MCB002    G/C BREAKER STATUS         On
MCB003    INTER-TIE BREAKER STAT     On
INTCOUNT  INTERRUPT COUNT             0
```

```
                    KEY PARAMETERS (ENGLISH UNITS)
/P  9061    06/20/95     1746:14          EVENTS:    0          OVERRIDE:   0
 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50
OWER OUTPUT (NET)          199.9   KWAC   OPERATING TIME          150.1   HRS
OWER OUTPUT (GROSS)        216.1   KWAC   POWER FACTOR            -1.00
TACK CURRENT              1084.4   AMPS   CUMULATIVE POWER        11.584  MWHR
TACK VOLTAGE               207.0   VOLTS  HALF STACK VOLTAGE       0.49   VOLTS
OLUMETRIC FUEL FLOW       1975.1   SCFH   FUEL FLOW SETPOINT      1992.6  SCFH
CTUAL FUEL FLOW             88.9   PPH
T010 EJECTOR POSITION       66.7   %      ZT010 SETPOINT            66.2  %
HI MONITOR                  1.00          TOTAL FUEL CONS         139496  SCF
T140 BURNER AIR FLOW       555.9   PPH    FT140 SETPOINT           533.3  PPH
E012 REFORMER TEMP        1663.2   DEGF   ZT110 POSITION            84.0  %
E012R BACKUP REF TEMP     1676.0   DEGF   TE012 SETPOINT          1655.6  DEGF

E002 HDS TEMP              581.9   DEGF   TE350 ANODE INLET TEMP 407.8   DEGF

E400FT STEAM SEP TEMP      350.5   DEGF   TE400 SETPOINT           350.1  DEGF
E881 TEMP TO CUST          177.1   DEGF   RECOVERED HEAT             254  MBTU/HR
                                          TE431 POLISHER TEMP      119.0  DEGF
T400 SEPARATOR LEVEL        11.2   IN     TE810 GLYCOL TEMP        153.3  DEGF
MP451 STATUS                 Off          TE160 MOTOR COMP AIR     113.1  DEGF
                                          TE150 MOT COMP AIR IN     99.2  DEGF
LECTRICAL EFFICIENCY        36.2   %      press <NEXT PAGE> key to view RM data
```

```
                         REACTANT SUPPLY SYSTEM
06/20/95   IDC=  1085.5  VDC= 207  KWACNET=  200  VT310DEL= -0.36  EVENTS  0
1746:55    FT012ACT=  88.3  TE400FT=  351  TE012FT=  1656          OVERRIDE  0
P/P  9061  P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE012      REF TUBE TEMP (PRIMARY) 1657.1  DEGF  SETPOINT:                1655.2
TE012R     REF TUBE TEMP (BACKUP)  1670.2  DEGF  REF/FUEL CONT OUTPUT:      1.08
TE012DEL   REF TUBE TEMP DELTA       14.5  DEGF
FT012ACT   ACTUAL MASS FUEL FLOW     88.3  PPH   SETPOINT:                  89.8
FT012      UNCORR. MASS FUEL FLOW    91.7  PPH   TE011 FUEL TEMP(DEGF)      99.0
SCFH       ACTUAL VOLUME FUEL FLOW 1962.2  CFH   SETPOINT:                1996.0
FUELTOT    TOTAL FUEL CONSUMED     139496  SCF   PT012 VENTURI(PSIA)        8.70

ZT010      EJECTOR POSITION          65.8  %     SETPOINT:                  65.7
PHIMON     PHI MONITOR               1.02        STEAM FLOW S.P.(PPH):     322.3
TE350      ANODE INLET TEMP         407.4  DEGF


TE002      HDS BED TEMP             582.8  DEGF  HTR002 STATUS:              Off


EFFREF    REFORMER EFFICIENCY       81.2  %
```

```
                        STACK LOOP, ANC LOOP, & WTS
06/20/95  IDC=  1089.6  VDC= 207  KWACNET=   200  VT310DEL= -0.37  EVENTS  0
1747:41   FT012ACT=  90.8  TE400FT= 351.5  TE012FT=   1651        OVERRIDE  0
P/P  9061 P 150 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE400     SEPARATOR TEMP (PRIMARY) 351.1  DEGF  SETPOINT:              350.4
TE400R    SEPARATOR TEMP (BACKUP)  350.7  DEGF  SEP TEMP FACTOR(DEGF)    0.9
TE400DEL  SEP TEMP DELTA             0.4  DEGF
LS450     WATER TANK LEVEL SWITCH    On         STK FLOW SW (FS400)      On
TE431     POLISHER TEMP            119.0  DEGF  F/W TEMP SW (TS451)      On
TE810     CONDENSOR EXIT TEMP      153.3  DEGF
TE820     CUST HEX HOT IN TEMP     177.5  DEGF  CUMHEATREC(MMBTU)     1.210
TE880     CUST HEX COLD IN TEMP    105.4  DEGF  FT880 FLOW (PPH)       2763
TE881     CUST HEX COLD EX TEMP    178.5  DEGF  HEAT REC (MBTU/HR)      202
TE401     STACK COOLANT INLET TEMP 316.6  DEGF
LT400     SEPARATOR LEVEL           10.8  IN

PMP451    WTS FEEDWATER PUMP         On         ON TIME, MIN.(FWPUMP):    0
STARTTEMP TEMP FOR REF HEATUP      350.0  DEGF
IDCNET    NET DC CURRENT          1092.8  AMPS

HTR400    ELEMENT "A"               Off         ELEMENT "C"             Off
          ELEMENT "B"               Off         ELEMENT "D"             Off
```

```
                        ELECTRICAL OVERVIEW
06/20/95  IDC=  1092  VDC= 207  KWACNET=  199.7  VT310DEL= -0.36  EVENTS  0
1748:44   FT012ACT=  92.5  TE400FT=  351  TE012FT=  1658        OVERRIDES  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME            150  HR
HOTTIME   TOTAL HOT TIME             210  HR
CELV      AVG VOLTS PER CELL        .646  V/C
ASF       CURRENT DENSITY            194  ASF
KWDC      DC KILOWATTS             224.5  KW
VT310DEL  DELTA HALF STK VOLT      -0.36  V     VT310 HALF STK VOLT      0.46
          INSTANTANEOUS STK AMPS    1078  A
EFFINV    INVERTER EFFICIENCY       96.0  %     CELL EFFICIENCY (%)      51.7
EFFMECH   MECHANICAL EFFICIENCY     92.4  %     REF EFFICIENCY (%)       79.2
EFFELEC   ELECTRICAL EFFICIENCY     36.3  %     HEAT RATE (BTU/KWHR)    10435

KWACNET   NET AC POWER             199.9  KWAC  DISPATCHED POWER:       200.0
PFACT     ACTUAL POWER FACTOR      -1.00  -     DISPATCHED P.F.:         1.00
KVARNET   NET KVAR                  -0.7  KVAR  DISPATCHED KVAR:          0.0
KVANET    NET KVA                  200.2  KVA
PARPOWER  PARASITE POWER            16.8  KW
KWACGROS  GROSS AC POWER           216.2  KW
MWHRSGR   GROSS AC MW HRS         14.718  MWHR
MWHRSNET  NET AC MW HOURS         11.591  MWHR
```

```
                                   POWER CONDITIONER SYSTEM
06/20/95  IDC= 1086  VDC= 207    KWACNET= 199.3  VT310DEL= -0.35  EVENTS  0
1749:30   FT012ACT=  89.7  TE400FT= 351.2  TE012FT= 1659.3        OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 30  I 50

PT001A    INV AC VOLTAGE,PHASE A   491.2  V
PT001B    INV AC VOLTAGE,PHASE B   489.9  V
PT001C    INV AC VOLTAGE,PHASE C   489.8  V
CT001A    INV AC CURRENT,PHASE A   225.1  A
CT001B    INV AC CURRENT,PHASE B   242.1  A
CT001C    INV AC CURRENT,PHASE C   239.5  A   CURRENT UNBAL (%)        7.1

PT003A    NET AC VOLTAGE,PHASE A   489.5  V
PT003B    NET AC VOLTAGE,PHASE B   486.3  V
PT003C    NET AC VOLTAGE,PHASE C   484.2  V   VOLTAGE UNBAL (%)        1.1
LINKVDC   LINK VOLTAGE             599.9  V

PERCFUND  PERCENT FUNDAMENTAL       88.8  %
PSREQ     PHASE SHIFT REQUEST        8.8  DEG
MCB001    G/I BREAKER STATUS         Off
MCB002    G/C BREAKER STATUS         On
MCB003    INTER-TIE BREAKER STAT     On
INTCOUNT  INTERRUPT COUNT              0
```

ONSI CORPORATION

TOTAL HARMONIC DISTORTION

DEMONSTRATED: 1.27 %
REQUIRED: < 3.00 %

RESULT: PASS

06/20/95 13:04:46

VOLTS = 483.7
AMPS = 0.04
WATTS = 17
P.F. = +1.00

HARM PWR = 0
Approx TDF = 0.95

	VOLTS	AMPS
TIF	5	77
THD	1.27%	17.39%
F	474.3V	0.04A
2	0.46%	13.04%
3	0.40%	4.35%
4	0.06%	4.35%
5	0.84%	4.35%
6	0.04%	0.00%
7	0.32%	4.35%
8	0.04%	0.00%
9	0.06%	0.00%
10	0.08%	4.35%
11	0.48%	4.35%
12	0.02%	0.00%
13	0.38%	4.35%
14	0.02%	0.00%
15	0.02%	0.00%
16	0.02%	0.00%
17	0.04%	0.00%
18	0.02%	0.00%
19	0.02%	0.00%
20	0.02%	0.00%
21	0.00%	0.00%
22	0.02%	0.00%
23	0.04%	4.35%
24	0.00%	0.00%
25	0.00%	0.00%

ONSI CORPORATION

OUTPUT FREQUENCY
(GRID CONNECT)

DEMONSTRATED: 60.00 HZ
REQUIRED: 60±3 HZ

RESULT: PASS

```
                              ELECTRICAL OVERVIEW
06/20/95  IDC=  1093  VDC= 207  KWACNET=  200.1  VT310DEL= -0.40  EVENTS  0
1522:17   FT012ACT=  90.1  TE400FT=  351  TE012FT=  1661         OVERRIDES  0
F/P  9061 F 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME  TOTAL LOAD TIME            150  HR
HOTTIME   TOTAL HOT TIME             211  HR
CELV      AVG VOLTS PER CELL        .646  V/C
ASF       CURRENT DENSITY            196  ASF
KWDC      DC KILOWATTS             226.7  KW
VT310DEL  DELTA HALF STK VOLT      -0.40  V     VT310 HALF STK VOLT      0.43
          INSTANTANEOUS STK AMPS    1091  A
EFFINV    INVERTER EFFICIENCY       95.6  %     CELL EFFICIENCY (%)      51.7
EFFMECH   MECHANICAL EFFICIENCY     92.2  %     REF EFFICIENCY (%)       81.1
EFFELEC   ELECTRICAL EFFICIENCY     36.5  %     HEAT RATE (BTU/KWHR)    10268

KWACNET   NET AC POWER             200.2  KWAC  DISPATCHED POWER:       200.0
PFACT     ACTUAL POWER FACTOR       0.99  -     DISPATCHED P.F.:         0.85
KVARNET   NET KVAR                  25.1  KVAR  DISPATCHED KVAR:        123.9
KVANET    NET KVA                  202.0  KVA
PARPOWER  PARASITE POWER            16.1  KW
KWACGROS  GROSS AC POWER           216.4  KW
MWHRSGR   GROSS AC MW HRS         14.641  MWHR
MWHRSNET  NET AC MW HOURS         11.704  MWHR
```

```
                              ELECTRICAL OVERVIEW
06/20/95   IDC=  1110   VDC= 206  KWACNET=  200.1   VT310DEL= -0.39  EVENTS  0
1829:02    FT012ACT=  88.8  TE400FT=  351  TE012FT=  1656         OVERRIDES  0
P/P  9061  P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

LOADTIME   TOTAL LOAD TIME                 150   HR
HOTTIME    TOTAL HOT TIME                  211   HR
CELV       AVG VOLTS PER CELL             .645   V/C
ASF        CURRENT DENSITY                 198   ASF
KWDC       DC KILOWATTS                  229.1   KW
VT310DEL   DELTA HALF STK VOLT           -0.39   V      VT310 HALF STK VOLT      0.43
           INSTANTANEOUS STK AMPS         1113   A
EFFINV     INVERTER EFFICIENCY            95.2   %      CELL EFFICIENCY (%)      51.6
EFFMECH    MECHANICAL EFFICIENCY          92.4   %      REF EFFICIENCY (%)       82.0
EFFELEC    ELECTRICAL EFFICIENCY          37.1   %      HEAT RATE (BTU/KWHR)    10198

KWACNET    NET AC POWER                  199.7   KWAC   DISPATCHED POWER:       200.0
PFACT      ACTUAL POWER FACTOR           -0.85   -      DISPATCHED P.F.:        -0.85
KVARNET    NET KVAR                     -122.6   KVAR   DISPATCHED KVAR:       -123.9
KVANET     NET KVA                       234.8   KVA
PARPOWER   PARASITE POWER                 17.4   KW
KWACGROS   GROSS AC POWER                217.2   KW
MWHRSGR    GROSS AC MW HRS              14.866   MWHR
MWHRSNET   NET AC MW HOURS              11.724   MWHR


                    KEY PARAMETERS (ENGLISH UNITS)
P/P  9061     06/20/95     1834:08          EVENTS:    0          OVERRIDE:    0
P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50
POWER OUTPUT (NET)       200.2  KWAC   OPERATING TIME          150.9   HRS
POWER OUTPUT (GROSS)     214.3  KWAC   POWER FACTOR            -1.00
STACK CURRENT           1077.0  AMPS   CUMULATIVE POWER       11.744   MWHR
STACK VOLTAGE            207.2  VOLTS  HALF STACK VOLTAGE       0.44   VOLTS
VOLUMETRIC FUEL FLOW    1943.4  SCFH   FUEL FLOW SETPOINT     1963.9   SCFH
ACTUAL FUEL FLOW          87.5  PPH
ZT010 EJECTOR POSITION    64.8  %      ZT010 SETPOINT           64.3   %
PHI MONITOR               1.02         TOTAL FUEL CONS        141110   SCF
FT140 BURNER AIR FLOW    536.8  PPH    FT140 SETPOINT          519.6   PPH
TE012 REFORMER TEMP     1660.1  DEGF   ZT110 POSITION           84.4   %
TE012R BACKUP REF TEMP  1672.9  DEGF   TE012 SETPOINT         1656.3   DEGF

TE002 HDS TEMP           595.5  DEGF   TE350 ANODE INLET TEMP  409.8   DEGF

TE400FT STEAM SEP TEMP   351.1  DEGF   TE400 SETPOINT          350.2   DEGF
TE881 TEMP TO CUST       134.0  DEGF   RECOVERED HEAT            912   MBTU/HR
                                       TE431 POLISHER TEMP     119.0   DEGF
LT400 SEPARATOR LEVEL     11.0  IN     TE810 GLYCOL TEMP       150.2   DEGF
PMP451 STATUS               On         TE160 MOTOR COMP AIR    119.0   DEGF
                                       TE150 MOT COMP AIR IN   101.9   DEGF
ELECTRICAL EFFICIENCY     37.4  %      press <NEXT PAGE> key to view RM data
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                         STACK LOOP, ANC LOOP, & WTS
06/20/95  IDC=  1066.4  VDC= 208  KWACNET=   199  VT310DEL= -0.37  EVENTS  0
1834:50   FT012ACT=  87.5  TE400FT= 350.7  TE012FT=   1656         OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE400     SEPARATOR TEMP (PRIMARY) 350.7  DEGF  SETPOINT:                350.2
TE400R    SEPARATOR TEMP (BACKUP)  350.0  DEGF  SEP TEMP FACTOR(DEGF)      0.9
TE400DEL  SEP TEMP DELTA             0.2  DEGF
LS450     WATER TANK LEVEL SWITCH    On         STK FLOW SW (FS400)        On
TE431     POLISHER TEMP            119.0  DEGF  F/W TEMP SW (TS451)        On
TE810     CONDENSOR EXIT TEMP      149.4  DEGF
TE820     CUST HEX HOT IN TEMP     176.6  DEGF  CUMHEATREC(MMBTU)        1.350
TE880     CUST HEX COLD IN TEMP     92.6  DEGF  FT880 FLOW (PPH)         22075
TE881     CUST HEX COLD EX TEMP    130.2  DEGF  HEAT REC (MBTU/HR)         840
TE401     STACK COOLANT INLET TEMP 299.7  DEGF
LT400     SEPARATOR LEVEL           11.2  IN

PMP451    WTS FEEDWATER PUMP        Off         ON TIME, MIN.(FWPUMP):       0
STARTTEMP TEMP FOR REF HEATUP      350.0  DEGF
IDCNET    NET DC CURRENT          1064.1  AMPS

HTR400    ELEMENT "A"               Off         ELEMENT "C"                Off
          ELEMENT "B"               Off         ELEMENT "D"                Off
```

```
                         STACK LOOP, ANC LOOP, & WTS
06/20/95  IDC=  1088.1  VDC= 207  KWACNET=   200  VT310DEL= -0.45  EVENTS  0
1934:51   FT012ACT=  91.6  TE400FT= 351.0  TE012FT=   1651         OVERRIDE  0
P/P  9061 P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE400     SEPARATOR TEMP (PRIMARY) 351.1  DEGF  SETPOINT:                350.4
TE400R    SEPARATOR TEMP (BACKUP)  350.1  DEGF  SEP TEMP FACTOR(DEGF)      0.9
TE400DEL  SEP TEMP DELTA             0.0  DEGF
LS450     WATER TANK LEVEL SWITCH    On         STK FLOW SW (FS400)        On
TE431     POLISHER TEMP            119.5  DEGF  F/W TEMP SW (TS451)        On
TE810     CONDENSOR EXIT TEMP      152.2  DEGF
TE820     CUST HEX HOT IN TEMP     180.6  DEGF  CUMHEATREC(MMBTU)        1.942
TE880     CUST HEX COLD IN TEMP    146.1  DEGF  FT880 FLOW (PPH)             0
TE881     CUST HEX COLD EX TEMP    179.9  DEGF  HEAT REC (MBTU/HR)           0
TE401     STACK COOLANT INLET TEMP 303.4  DEGF
LT400     SEPARATOR LEVEL           10.8  IN

PMP451    WTS FEEDWATER PUMP        On          ON TIME, MIN.(FWPUMP):       0
STARTTEMP TEMP FOR REF HEATUP      350.0  DEGF
IDCNET    NET DC CURRENT          1087.2  AMPS

HTR400    ELEMENT "A"               Off         ELEMENT "C"                Off
          ELEMENT "B"               Off         ELEMENT "D"                Off
```

```
                         KEY PARAMETERS (ENGLISH UNITS)
P/P  9061    06/20/95     2034:51          EVENTS:   0           OVERRIDE:   0
P 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50
POWER OUTPUT (NET)          200.2  KWAC   OPERATING TIME          152.9  HRS
POWER OUTPUT (GROSS)        215.7  KWAC   POWER FACTOR             1.00
STACK CURRENT              1086.0  AMPS   CUMULATIVE POWER        12.144 MWHR
STACK VOLTAGE               206.7  VOLTS  HALF STACK VOLTAGE       0.39  VOLTS
VOLUMETRIC FUEL FLOW       1994.2  SCFH   FUEL FLOW SETPOINT     1997.0  SCFH
ACTUAL FUEL FLOW             89.8  PPH
ZT010 EJECTOR POSITION       66.9  %      ZT010 SETPOINT           66.2  %
PHI MONITOR                  1.01         TOTAL FUEL CONS        145056  SCF
FT140 BURNER AIR FLOW       517.7  PPH    FT140 SETPOINT          517.8  PPH
TE012 REFORMER TEMP        1652.2  DEGF   ZT110 POSITION           85.2  %
TE012R BACKUP REF TEMP     1661.9  DEGF   TE012 SETPOINT         1657.1  DEGF

TE002 HDS TEMP              603.9  DEGF   TE350 ANODE INLET TEMP 409.8  DEGF

TE400FT STEAM SEP TEMP      350.9  DEGF   TE400 SETPOINT          350.2  DEGF
TE881 TEMP TO CUST          180.4  DEGF   RECOVERED HEAT            101  MBTU/HR
                                          TE431 POLISHER TEMP     121.9  DEGF
LT400 SEPARATOR LEVEL        11.0  IN     TE810 GLYCOL TEMP       153.3  DEGF
PMP451 STATUS                 Off         TE160 MOTOR COMP AIR    107.6  DEGF
                                          TE150 MOT COMP AIR IN    93.1  DEGF
ELECTRICAL EFFICIENCY        37.4  %      press <NEXT PAGE> key to view RM data
```

ONSI CORPORATION

FUEL CONSUMPTION

TIME	CUMULATIVE FUEL CONSUMED
1834:08	141,110 SCF
2034:51	145,086 SCF

ELAPSED TIME:	2.012 HRS
INCREMENTAL FUEL CONSUMED:	3976 SCF
AVG. VOLUMETRIC FUEL FLOW RATE:	1976 SCFH
REQUIRED FUEL FLOW RATE:	1900 ± 100 SCFH

RESULT: PASS

```
                         STACK LOOP, ANC LOOP, & WTS
06/20/95   IDC=  1086.1  VDC= 207  KWACNET=   199  VT310DEL= -0.44  EVENTS  0
2035:32    FT012ACT=  89.9  TE400FT= 350.8  TE012FT=    1655        OVERRIDE  0
P/P  9061 F 160 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 50

TE400      SEPARATOR TEMP (PRIMARY) 350.9  DEGF  SETPOINT:                350.1
TE400R     SEPARATOR TEMP (BACKUP)  350.9  DEGF  SEP TEMP FACTOR(DEGF)      0.9
TE400DEL   SEP TEMP DELTA             0.0  DEGF
LS450      WATER TANK LEVEL SWITCH    On         STK FLOW SW (FS400)         On
TE431      POLISHER TEMP            121.9  DEGF  F/W TEMP SW (TS451)         On
TE810      CONDENSOR EXIT TEMP      154.0  DEGF
TE820      CUST HEX HOT IN TEMP     188.0  DEGF  CUMHEATREC(MMBTU)        1.997
TE880      CUST HEX COLD IN TEMP    150.7  DEGF  FT880 FLOW (PPH)          2591
TE881      CUST HEX COLD EX TEMP    182.0  DEGF  HEAT REC (MBTU/HR)          83
TE401      STACK COOLANT INLET TEMP 316.8  DEGF
LT400      SEPARATOR LEVEL           10.8  IN

PMP451     WTS FEEDWATER PUMP        Off         ON TIME, MIN.(FWPUMP):       0
STARTTEMP  TEMP FOR REF HEATUP      350.0  DEGF
IDCNET     NET DC CURRENT          1081.8  AMPS

HTR400     ELEMENT "A"               Off         ELEMENT "C"                Off
           ELEMENT "B"               Off         ELEMENT "D"                Off
```

ONSI CORPORATION

HEAT RECOVERY

TIME	CUMULATIVE HEAT RECOVERY
1834:50	1,350,000 BTU
2035:32	1,997,000 BTU

ELAPSED TIME: 2.012 HRS

INCREMENTAL HEAT RECOVERY: 647,000 BTU

AVERAGE RATE OF HEAT RECOVERY: 321,570 BTU/HR.

```
                           KEY PARAMETERS (ENGLISH UNITS)
P/P  9061    06/21/95      0935:15            EVENTS:   0          OVERRIDE:   0
P 161 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 80
POWER OUTPUT (NET)          38.1  KWAC   OPERATING TIME          166.0  HRS
POWER OUTPUT (GROSS)        90.3  KWAC   POWER FACTOR             0.95
STACK CURRENT              410.4  AMPS   CUMULATIVE POWER       14.561  MWHR
STACK VOLTAGE              227.9  VOLTS  HALF STACK VOLTAGE      -0.00  VOLTS
VOLUMETRIC FUEL FLOW       711.9  SCFH   FUEL FLOW SETPOINT      717.6  SCFH
ACTUAL FUEL FLOW            32.0  PPH
ZT010 EJECTOR POSITION      23.2  %      ZT010 SETPOINT           21.8  %
PHI MONITOR                 1.07         TOTAL FUEL CONS        169280  SCF
FT140 BURNER AIR FLOW      250.4  PPH    FT140 SETPOINT          253.7  PPH
TE012 REFORMER TEMP       1515.5  DEGF   ZT110 POSITION           45.5  %
TE012R BACKUP REF TEMP    1510.2  DEGF   TE012 SETPOINT         1527.3  DEGF

TE002 HDS TEMP             603.0  DEGF   TE350 ANODE INLET TEMP  406.7  DEGF

TE400FT STEAM SEP TEMP     364.0  DEGF   TE400 SETPOINT          363.4  DEGF
TE881 TEMP TO CUST         162.1  DEGF   RECOVERED HEAT            237  MBTU/HR
                                         TE431 POLISHER TEMP     105.2  DEGF
LT400 SEPARATOR LEVEL       10.9  IN     TE810 GLYCOL TEMP       151.3  DEGF
PMP451 STATUS                On          TE160 MOTOR COMP AIR    100.8  DEGF
                                         TE150 MOT COMP AIR IN    84.0  DEGF
ELECTRICAL EFFICIENCY       18.4  %      press <NEXT PAGE> key to view RM data
```

```
                            REACTANT SUPPLY SYSTEM
06/21/95  IDC=   398.5  VDC= 229  KWACNET=   31  VT310DEL= -0.83  EVENTS  0
0936:14   FT012ACT=  32.0  TE400FT=  363  TE012FT=  1518        OVERRIDE  0
P/P  9061 P 161 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 80

TE012      REF TUBE TEMP (PRIMARY) 1518.2  DEGF  SETPOINT:              1526.8
TE012R     REF TUBE TEMP (BACKUP)  1511.6  DEGF  REF/FUEL CONT OUTPUT:    1.04
TE012DEL   REF TUBE TEMP DELTA        6.5  DEGF
FT012ACT   ACTUAL MASS FUEL FLOW     32.0  PPH   SETPOINT:                31.7
FT012      UNCORR. MASS FUEL FLOW    36.1  PPH   TE011 FUEL TEMP(DEGF)    85.4
SCPH       ACTUAL VOLUME FUEL FLOW  710.9  CPH   SETPOINT:               700.5
FUELTOT    TOTAL FUEL CONSUMED     169292  SCF   PT012 VENTURI(PSIA)      7.15

ZT010      EJECTOR POSITION          22.9  %     SETPOINT:                21.6
PHIMON     PHI MONITOR               1.04        STEAM FLOW S.P.(PPH):   134.4
TE350      ANODE INLET TEMP         406.7  DEGF


TE002      HDS BED TEMP             602.1  DEGF  HTR002 STATUS:            Off


EFFREF   REFORMER EFFICIENCY         83.7  %
```

```
                         STACK LOOP, ANC LOOP, & WTS
06/21/95   IDC=   490.8  VDC= 222  KWACNET=    54  VT310DEL= -0.80  EVENTS  0
0937:57    FT012ACT=  40.4  TE400FT= 362.5  TE012FT=   1520      OVERRIDE  0
P/P  9061 P 161 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 80

TE400      SEPARATOR TEMP (PRIMARY) 362.5  DEGF  SETPOINT:              358.8
TS400R     SEPARATOR TEMP (BACKUP)  362.1  DEGF  SEP TEMP FACTOR(DEGF)    1.0
TS400DEL   SEP TEMP DELTA             0.4  DEGF
LS450      WATER TANK LEVEL SWITCH    On         STK FLOW SW (FS400)      On
TE431      POLISHER TEMP            105.2  DEGF  F/W TEMP SW (TS451)      On
TE810      CONDENSOR EXIT TEMP      153.3  DEGF
TE820      CUST HEX HOT IN TEMP     186.1  DEGF  CUMHEATREC(MMBTU)      3.231
TE880      CUST HEX COLD IN TEMP    150.5  DEGF  FT880 FLOW (PPH)       22247
TE881      CUST HEX COLD EX TEMP    160.6  DEGF  HEAT REC (MBTU/HR)       224
TS401      STACK COOLANT INLET TEMP 346.1  DEGF
LT400      SEPARATOR LEVEL           11.3  IN

PMP451     WTS FEEDWATER PUMP         Off        ON TIME, MIN.(FWPUMP):     0
STARTTEMP  TEMP FOR REF HEATUP      350.0  DEGF
IDCNET     NET DC CURRENT           209.3  AMPS

HTR400     ELEMENT "A"                On         ELEMENT "C"              On
           ELEMENT "B"                On         ELEMENT "D"              Off
```

```
                          ELECTRICAL OVERVIEW
06/21/95   IDC=   452  VDC= 225  KWACNET=   44.5  VT310DEL= -0.85  EVENTS  0
0938:12    FT012ACT=  35.0  TS400FT=  361  TE012FT=  1526      OVERRIDES  0
P/P  9061 P 161 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 80

LOADTIME   TOTAL LOAD TIME             166  HR
HOTTIME    TOTAL HOT TIME              225  HR
CELV       AVG VOLTS PER CELL         .704  V/C
ASF        CURRENT DENSITY              81  ASF
KWDC       DC KILOWATTS              102.1  KW
VT310DEL   DELTA HALF STK VOLT       -0.85  V     VT310 HALF STK VOLT    -0.02
           INSTANTANEOUS STK AMPS      452  A
EFFINV     INVERTER EFFICIENCY        97.4  %     CELL EFFICIENCY (%)     56.1
EFFMECH    MECHANICAL EFFICIENCY      50.1  %     REF EFFICIENCY (%)      88.4
EFFELEC    ELECTRICAL EFFICIENCY      23.8  %     HEAT RATE (BTU/KWHR)   16152

KWACNET    NET AC POWER               44.5  KWAC  DISPATCHED POWER:        0.0
PFACT      ACTUAL POWER FACTOR        0.95  -     DISPATCHED P.F.:        1.00
KVARNET    NET KVAR                   14.5  KVAR  DISPATCHED KVAR:         0.0
KVANET     NET KVA                    46.8  KVA
PARPOWER   PARASITE POWER             54.6  KW
KWACGROS   GROSS AC POWER             99.1  KW
MWHRSGR    GROSS AC MW HRS          17.986  MWHR
MWHRSNET   NET AC MW HOURS          14.563  MWHR
```

```
                                  POWER CONDITIONER SYSTEM
06/21/95   IDC=  427   VDC= 227    KWACNET=  42.6  VT310DEL= -0.81   EVENTS  0
0939:11    FT012ACT=  35.6  TE400FT= 361.9  TE012FT= 1525.2         OVERRIDE  0
F/P  9061 P 161 R 160 S 60  W 20  A 30  N 40  C 30  L 10  I 80

PT001A     INV AC VOLTAGE,PHASE A    482.9  V
PT001B     INV AC VOLTAGE,PHASE B    480.0  V
PT001C     INV AC VOLTAGE,PHASE C    478.9  V
CT001A     INV AC CURRENT,PHASE A     52.3  A
CT001B     INV AC CURRENT,PHASE B     54.9  A
CT001C     INV AC CURRENT,PHASE C     47.5  A   CURRENT UNBAL (%)        14.3

PT003A     NET AC VOLTAGE,PHASE A    485.4  V
PT003B     NET AC VOLTAGE,PHASE B    482.7  V
PT003C     NET AC VOLTAGE,PHASE C    480.7  V   VOLTAGE UNBAL (%)         1.0
LINKVDC    LINK VOLTAGE              599.9  V

PERCFUND   PERCENT FUNDAMENTAL        85.4  %
PSREQ      PHASE SHIFT REQUEST         2.0  DEG
MCB001     G/I BREAKER STATUS          On
MCB002     G/C BREAKER STATUS          Off
MCB005     INTER-TIE BREAKER STAT      Off
INTCOUNT   INTERRUPT COUNT              0
```

DEMONSTRATED OUTPUT VOLTAGE: 478.9 TO 482.9 VAC
REQUIRED OUTPUT VOLTAGE: 480 ± 3% VAC

RESULT: PASS

ONSI CORPORATION

OUTPUT FREQUENCY
(GRID INDEPENDENT)

DEMONSTRATED:	59.99 HZ
REQUIRED:	60±3 HZ
RESULT:	PASS

Appendix B: MCAGCC Twentynine Palms – Naval Hospital, Project Meeting Attendees

Site Evaluation, 8-9 December 1993

Attendees	Organization
Mike Binder	USACERL
T. Monaco	Naval Hospital
M.J. Roman	Naval Hospital
Lt. C.R. Miranda	Naval Hospital
Patrick Dougherty	Naval Hospital
LCDR Brannman	Naval Hospital
E.P. Thompson	Naval Hospital
S.D. Hammons	MCAGCC
Gerry Merten	SAIC
Mike Torrey	SAIC

Kick-off Meeting, 03 May 1994

Attendees	Organization
Gerald Cler	USACERL
T. Monaco	Naval Hospital
K.J. Kouser	Naval Hospital
C.J. Chitwood	Naval Hospital
S.D. Hammons	MCAGCC
Howard DeVore	Public Works
Wayne Hofeldt	Southern California Edison
Mike Torrey	SAIC
Douglas Young	United Technologies/ONSI

Design Review, 02 March 1995

Attendees	Organization
Mike Binder	USACERL
Gerald Cler	USACERL
Bill Taylor	USACERL
T. Monaco	Naval Hospital
S.D. Hammons	MCAGCC
Howard DeVore	Public Works
Andrew Dufour	MCAGCC
George Collard	GBC Electrical Services
Ray Aselin	GBC Electrical Services
Gerry Merten	SAIC
Douglas Young	United Technologies/ONSI

Acceptance Test, 23 June 1995

Attendees	Organization
Mike Binder	USACERL
Frank Holcomb	USACERL
T. Monaco	Naval Hospital
Luke Wren	Facilities Management
Douglas Young	United Technologies/ONSI
George Collard	GBC Electrical Services

Appendix C: Review Letters for Original Design Drawings

Science Applications International Corporation
An Employee-Owned Company

February 14, 1995

Dr. Mike Binder
USACERL
Energy and Utilities Systems Division
2902 Newmark Drive
Champaign, IL 61821-1076

Subject: Twenty-Nine Palms Final Design Review

Dear Mike:

SAIC and our licensed mechanical and electrical subcontractors have reviewed the fuel cell installation design drawings for the Twenty-Nine Palms Marine Corps. Base. Our comments are presented below.

1. HEAT REJECTION LOOP (COOLING MODULE)

   a. Assumed 30 gpm flow rate.
   b. Total equivalent piping length of 335 feet.
   c. Pressure drop - 30 gpm in 2" pipe = 2'/100'.
   d. Fluid cooler pressure drop - 12' at 30 gpm.
   e. Total pressure drop external to fuel cell is (3.35' x 2') + 12' = 18.7'

   Pipe sizing and velocity are adequate at 2". Discharge head for circulating pump located in fuel cell power module should include the 18.7' piping loop pressure drop.

2. HEAT RECOVERY PIPING - CUSTOMER SIDE

   a. Flow rate - 50 gpm.
   b. Total equivalent piping length - 318 feet.
   c. Pipe size - 3"
   d. Pressure drop - 25 gpm in 3" pipe = 0.8/100'.
   e. Piping pressure loss = 3.18 x 0.8 = 2.8'
   f. Pressure drop through HEX880 (in power module) = 15' ±
   g. Total pump head required = 2.8' + 15' = 17.7'

   Piping sizing and velocity are adequate at 3"; however, as the velocity is low at 2.3 feet per second, some savings could be realized by utilizing 2" pipe versus 3". A check valve is recommended at the discharge of Recirculating Pump P-2.

10260 Campus Point Drive, San Diego, California 92121-1578 (619) 546-6000

3. HEAT RECOVERY PIPING - FUEL CELL SIDE (HEX880 TO STORAGE TANK LOOP W/P-1)

a. Flow rate - 25 gpm
b. Pipe size - assume 2"
c. Total equivalent piping length - 221'
d. Pressure drop - 25 gpm in 2" pipe = 1.5'/100'
e. Piping pressure loss = 2.21 x 1.5 = 3.3'
f. Pressure drop through HEX880 = 15' ±
g. Total pump head required = 3.3' + 15' = 18.3'

Piping sizing and velocity are adequate at 2". The B&G Series 90, size 1-1/2A, 1/2 H.P. pump is adequate.

4. CITY WATER TO FUEL CELL POWER MODULE

a. Flow rate - assume 10 gpm ±
b. Water pressure - assume 50 psig ±
c. Total equivalent piping length - 156'
d. Pressure drop - 10 gpm in 3/4" pipe = 10 psig/100'
e. Pressure drop through HEX880 - assume 15'
f. Total pressure drop then is (1.56 x 10) + (15; x .43) = 22 psig. The 3/4" pipe size is adequate assuming that about 28 psig at the fuel cell inlet is satisfactory.

Should the City water supply not be isolated from the potable system elsewhere in the plant, an approved backflow prevention device should be provided.

5. NATURAL GAS

a. Connected load - 1,900 CFH.
b. Pipe size - 3"
c. Pressure at point-of-connection - assume under 14" W.C.
b. Total equivalent piping length - 180'.
c. Maximum delivery capacity of 0.60 specific gravity natural gas per hour with pressure drop of 0.5 inch water column in 3" pipe is 2,257 CFH. Pipe sizing at 3" is adequate.

6. NITROGEN

a. Required flow rate - could not be determined from data provided.
b. Pipe size - 3/4"
b. Total equivalent piping length = 60'.

Assuming a required delivery pressure of 50 psig at the fuel cell power module connection, capacity of a 3/4" pipe is in excess of 1,600 liters per minute. This pipe size should be adequate depending on ONSI's maximum anticipated flow rate

5. ELECTRICAL

a. The plans should be stamped by a registered electrical engineer.
b. More details should be given for the new 400A subpanel; i.e., mounting AIC, breaker sizes, etc.
c. The sizes of conduits and conductors from new sub-panel to "NTH" and "HNH" should be given.
d. The 120V power source to the fuel cell power module should be shown.
e. Show ground grid around fuel cell enclosure and all termination points.
f. Show routing to room F005 along with feeder length and voltage drop.

Based on the 105ºF and 140ºF supply temperatures for the domestic hot water loops, the 1,000 gallon storage tank appears adequate. The detailed electrical and thermal designs are sufficient. With consideration of the above comments, we believe that the site design is adequate to proceed with construction.

Sincerely,

Gerry

Gerry Merten
Division Manager,
Advanced Energy Systems

29 PALMS "RECORD DRAWING" CHANGES

6/19/95
J. STENIUNAS

DRAWING	CHANGE
S-1	Equipment positioning adjustments including nitrogen rack to back side of pad Fence lengthened 1 ft to 52 ft Full concrete pad within fence Drainage accommodations at building end of pad
S-2	Equipment position adjustments
ME-1	Equipment repositioned as on S-1 Gas line repositioned Spare conduit added (emergency power cord) Building wall penetrations noted Disconnect labels changed (reversed GC & GI)
M-1	Storage tank dimension typo corrected Mixing valves labeled (inlets B&C, outlet A) Closed valves illustrated
M-2	No changes
E-1	Grounding illustration changed to correspond to ground grid on 9061 E-3 drawing
E-2	No changes
E-3	Ground grid updated.

Appendix D: PC25B Fuel Cell Forced Outage Description Codes

Fleet Log
Model B

page1

FORCED OUTAGE ORIGIN BY POWER PLANT

DESCRIPTION	CODE1	CODE2	CODE3
POWER SECTION SYSTEM	PSS		
FREEZE PREVENTION HEATER A			HTR310A
FREEZE PREVENTION HEATER B			HTR310B
GROUND FAULT DETECTOR			GFD-001
HALF-STACK VOLTAGE MONITOR			VT310
FUEL PROCESSING SYSTEM	FPS		
SHUTOFF VALVE			CV000
SHUTOFF VALVE			CHV100
CHECK VALVE			CV100
FLOW CONTROL VALVE			FCV012
EJECTOR			EJT010
REFORMER			REF300
LOW TEMP SHIFT CONVERTER			SC300
AIR PRE-HEATER			HEX910
BURNER CONTROL			BSC001
INTEGRATED LOW TEMP SYSTEM		ILS	
AIR PROCSSING SYSTEM	APS		
FILTER			FIL100
PROCESS AIR BLOWER			BLO100
CATHODE			FCV100
CATHODE AIR VALVE			FCV110
REFORMER BURNER			FCV140
VALVE POSITION INDICATIOR			ZT110
AIR FLOW TRANSMITTER			FT140
HAND ORIFICE			HO135
FIXED ORIFICE			FO130
REFORMER BURNER SENSOR			BE030
THERMAL MANAGEMENT SYSTEM	TMS		
FLOW SWITCH			FS400
THERMAL TEMP MANAGEMENT CONTROL			TE400
THERMAL TEMP MANAGEMENT CONTROL			TE431
CELL STACK COOLING H20 SUB-SYSTEM		CSCW	
COOLANT ACCUMULATOR			ACC400
COOLANT PUMP			PMP400
THERMAL CONTROL HEAT EXCHANGER			HEX400
FLOW ORIFICE			FO400
FLOW ORIFICE			FO420
BLOWDOWN COOLER			HEX310
BLOWDOWN VALVE			FCV430
MIXED RESIN DEMINERALIZER BED			DMN440
ELECTRIC HEATER			HTR400
MOTORIZED VALVE			TCV400
ANCILLARY COOLANT SUB-SYSTEM		ACS	
PUMP			PMP830
BLOWDOWN COOLER			HEX431
CONDENSER			HEX920
CUSTOMER HEAT EXCHANGER			HEX880
FORCED CONVECTION COOLING MODULE			HEX800
SELF-ACTUATED FLOW CONTROL VALVE			TCV800
MOTORIZED VALVE			TCV830
HAND ORIFICE			HO840
WATER TREATMENT SYSTEM	WTS		
WTS PUMP			PMP450
ORGANIC FILTER			ORG450
MIXED RESIN DEMINERALIZER BED			DMN450A
MIXED RESIN DEMINERALIZER BED			DMN450B
MIXED RESIN DEMINERALIZER BED			DMN450C
MIXED RESIN DEMINERALIZER BED			DMN450D

CHANGE IN STATE

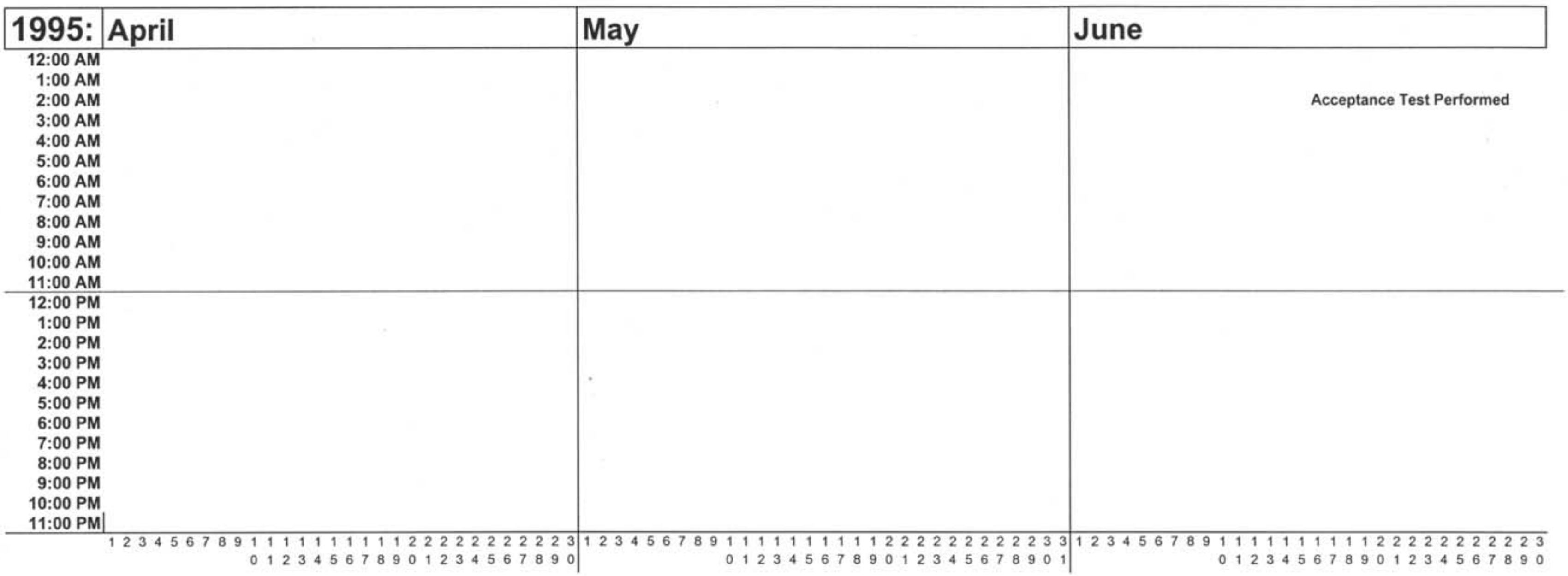
DESCRIPTION	CODE
POWER UP	PU
POWER DOWN	PD
IDLE UP	IU
IDLE DOWN	ID
SHUTDOWN	S
NONE	N

FORCED OUTAGE/ UNFORCED OUTAGE

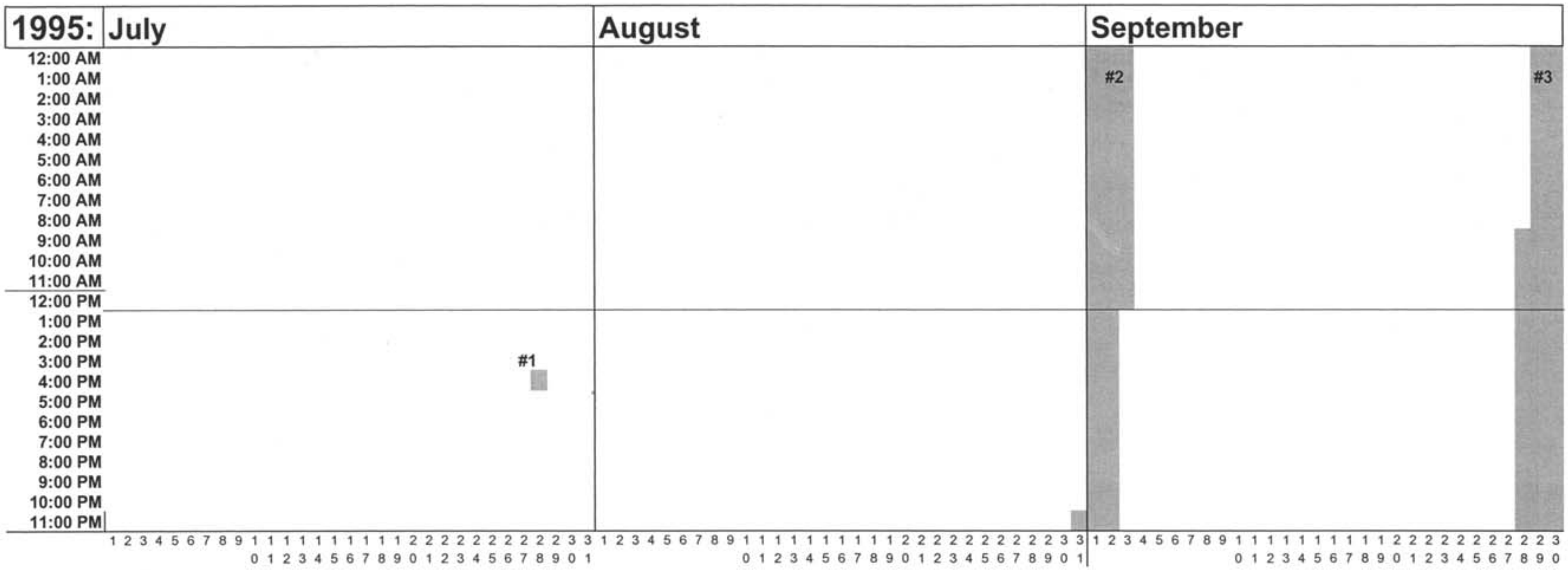
DESCRIPTION	CODE
FORCED	F
UNFORCED	U

			Fleet Log Model B
FEEDWATER PUMP			PMP451
ISOLATION HAND VALVE			HV450A
ISOLATION HAND VALVE			HV450B
WATER TANK LEVEL TRANSMITTER			LS450
WATER TANK LEVEL TRANSMITTER			LS451
WATER TANK LEVEL TRANSMITTER			LT450
WATER LEVEL CONTROL VALVE			LCV451
CHECK VALVE			CHV451
NITROGEN PURGE SYSTEM	NPS		
OPEN SOLENOID VALVE			CV720
OPEN SOLENOID VALVE			CV710
FLOW ORIFICE			FO720
AIR EJECTOR			EJT710
CABINET VENTILATION SYSTEM	CVS		
VENTILATION FAN			FAN165
VENTILATION FAN			FAN150
FLOW SWITCH			FS165
FILTER			FIL150
FLOW CONTROL DAMPER			FCD150
EXIT FLOW RATE CONTROL			TE150B
TO PROCESSED STEAM SHUTOFF VALVE			CV500
ELECTRICAL SYSTEM	ES		
POWER CONDITIONING SYSTEM		PCS	
MOTORIZED AC CURCUIT BREAKER			MCB001
MOTORIZED AC CURCUIT BREAKER			MCB002
MOTORIZED AC CURCUIT BREAKER			MCB003
POWER DISTRIBUTION SYSTEM		PDS	
AUXILIARY TRANSFORMER			T005
UNINTERUPTABLE POWER SUPPLY			UPS001
POWER PLANT CONTROL		PPC	
LOCAL OPERATING INTERFACE			LOI
LOCAL DIAGNOSTIC TERMINAL			LDT
ELECTICAL CONTROL SYSYEM		ECS	
OTHER	OTR		
OTHER ELECTRICAL		OTRE	
K001			K001
K002			K002
INVERTER			INV
CSA			CSA
PC CARD			PC
BOOST REGULATOR			BSRG
FUSE			FUSE
POLE FAULT			POLE
BRIDGE FAULT			BRDG
QUAD POWER SUPPLY			QUAD
DUAL POWER SUPPLY			DUAL
RELAY TRIP			RELAY
GROUND FAULT			GRND
CIRCUIT BREAKER			CRB
CONTROLLER			CRL
SUBSTACK			SBSTK
GRID DISTIRBANCE			GRID
OTHER GAS		OTRG	
OTHER WATER		OTRW	

Appendix E: Operational and Outage Periods

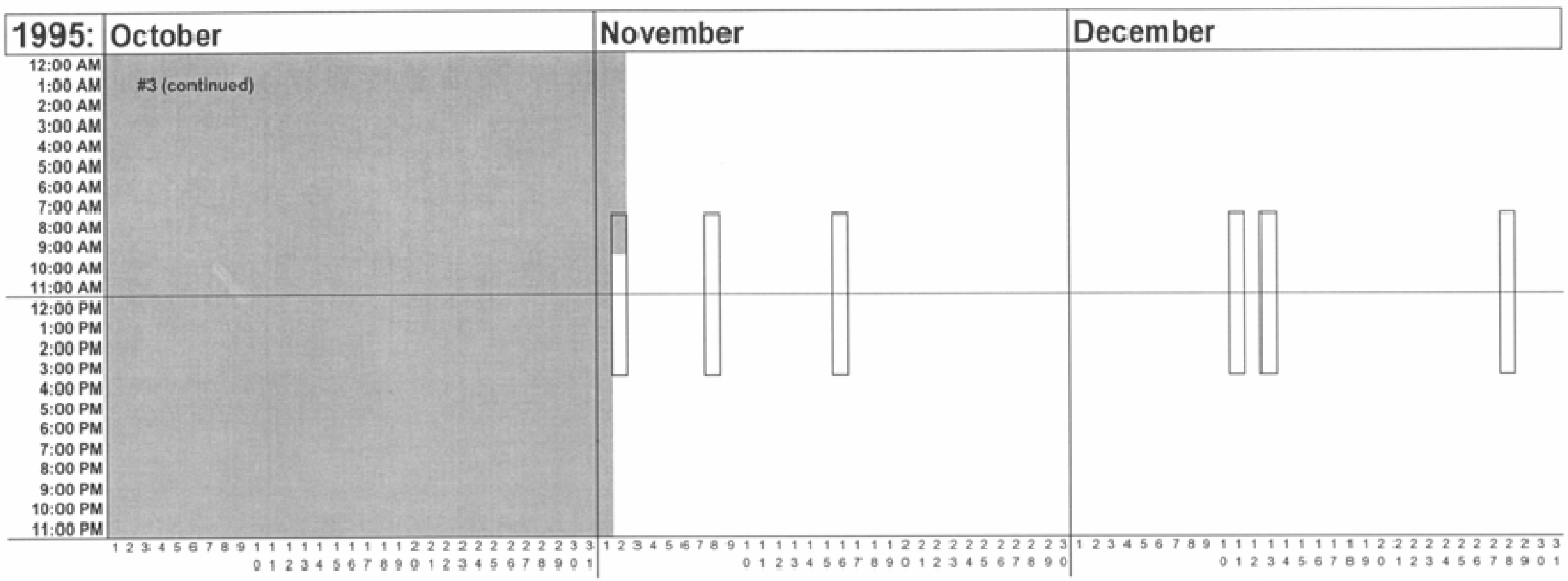


Outage #	Duration	Description
		Acceptance Test performed between June 16th through June 21st.

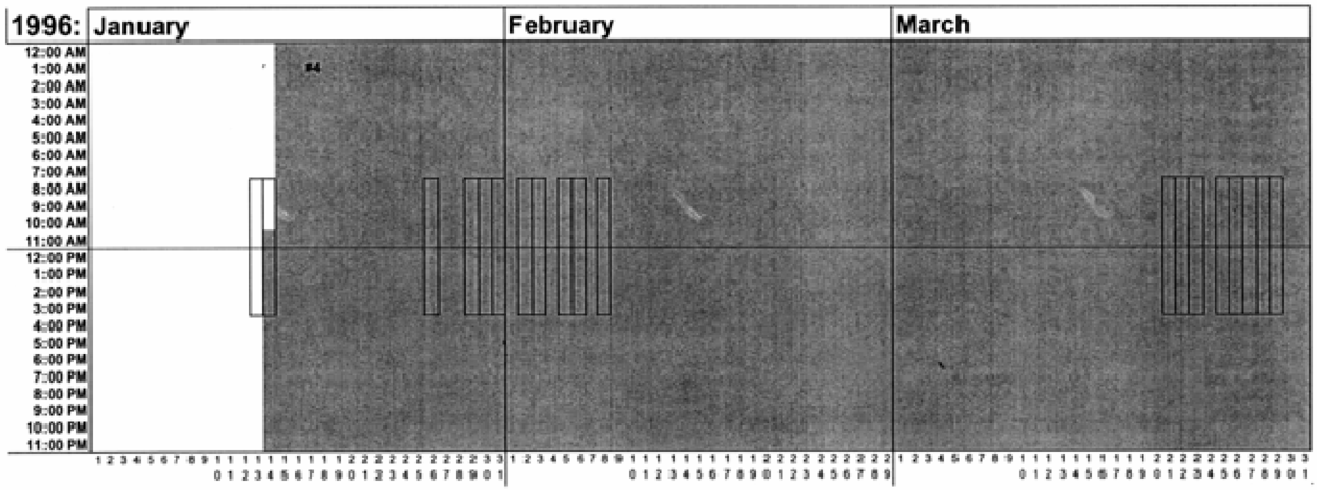


Outage #	Duration	Description
1	00:33	APS: FT140 low in R80-R160 shutdown (while adjusting electro-mechanical brake to prevent unstable FCV1140 operation)
2	60:12	TMS/CSW: Loss of separator control (SEPDEL high for 10min in S60) restarted raised power slowly.
3	840:20	TMS/CSW: Low HDS bed temperature (TE002 low for 60sec in R110-R160). Completed 2000 hour maintenance. Replaced FCV503. Replaced FO002 orifice with 1.1" size. Replaced PMP400 with high flow pump to improve TE401. Replaced PC7 controller card.

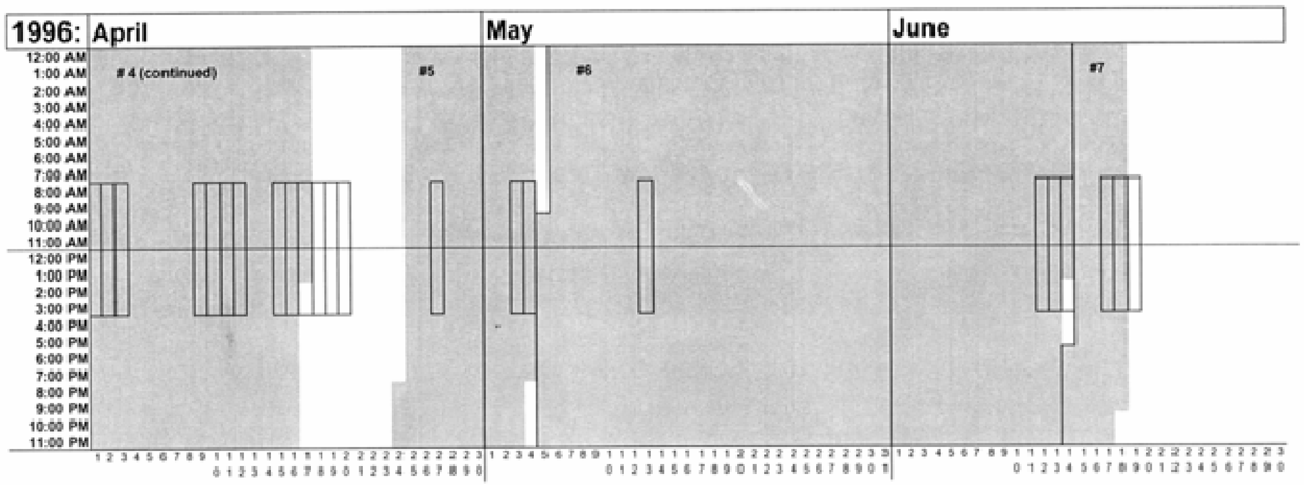
Detailed Fuel Cell Demonstration Site Summary Report
MCAGCC Twentynine Palms



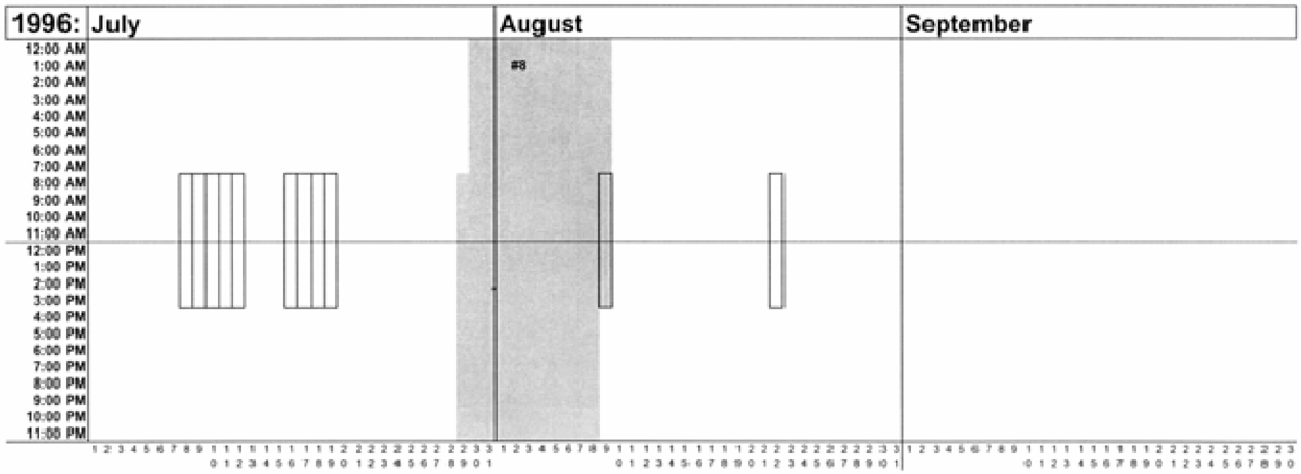
Outage #	Duration	Description
3	840:20	See previous page.



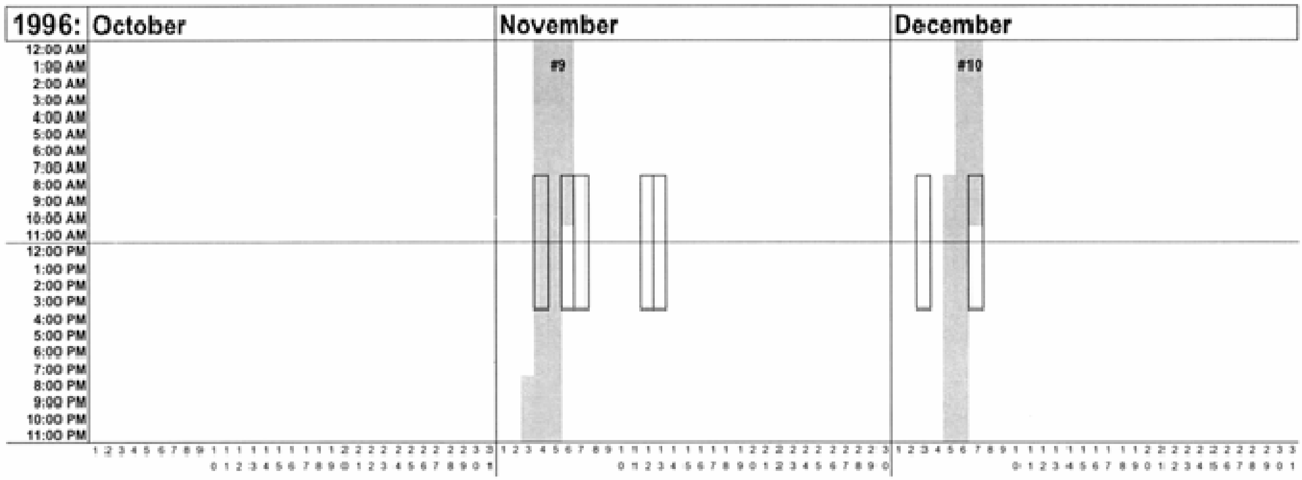
Outage #	Duration	Description
4	2,259:42	Keyboard shutdown to investigate two low sub stack voltage readings. Fuel cell stack removed February 8th. New fuel cell stack installed March 28th. Fuel cell restarted on April 17th.



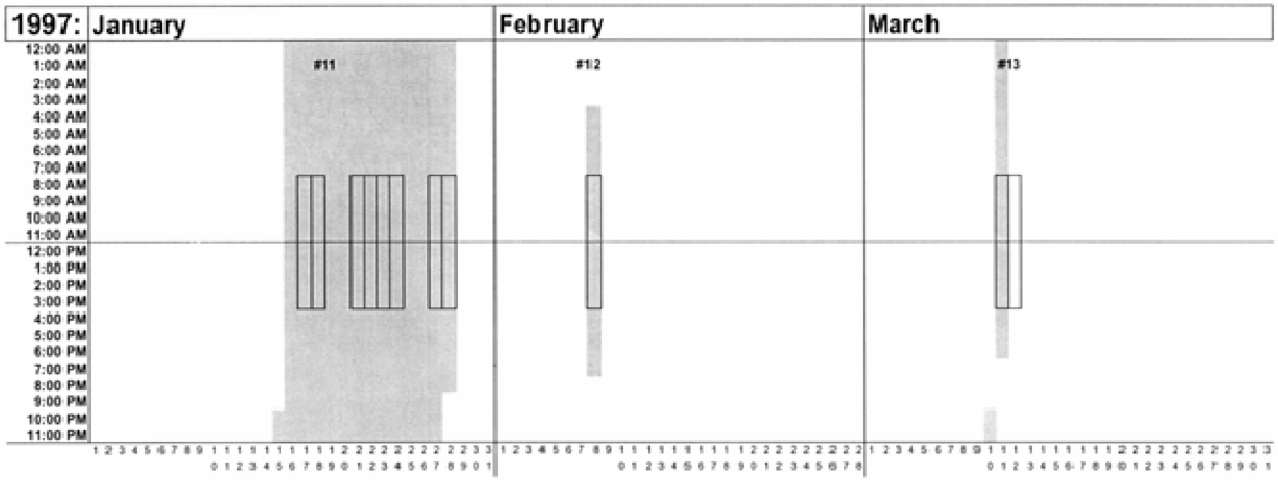
Outage #	Duration	Description
4	2,259:42	See previous page.
5	238:47	CVS: Power plant shutdown due to low level in water tank. Restarts unsuccessful due to reformer burner flame outs, CV500 stuck open. CV500 replaced on 5/3.
6	963:07	ES: Power plant shutdown due to K002 circuit breaker sequence error upon a site power loss. Problem traced to bad talk-back relay (K6) associated with MCB001. SCG assisted with repairs.
7	100:34	ES: Power plant shutdown. Inverter sequence error. Control relay and breaker (MCB002) replaced.



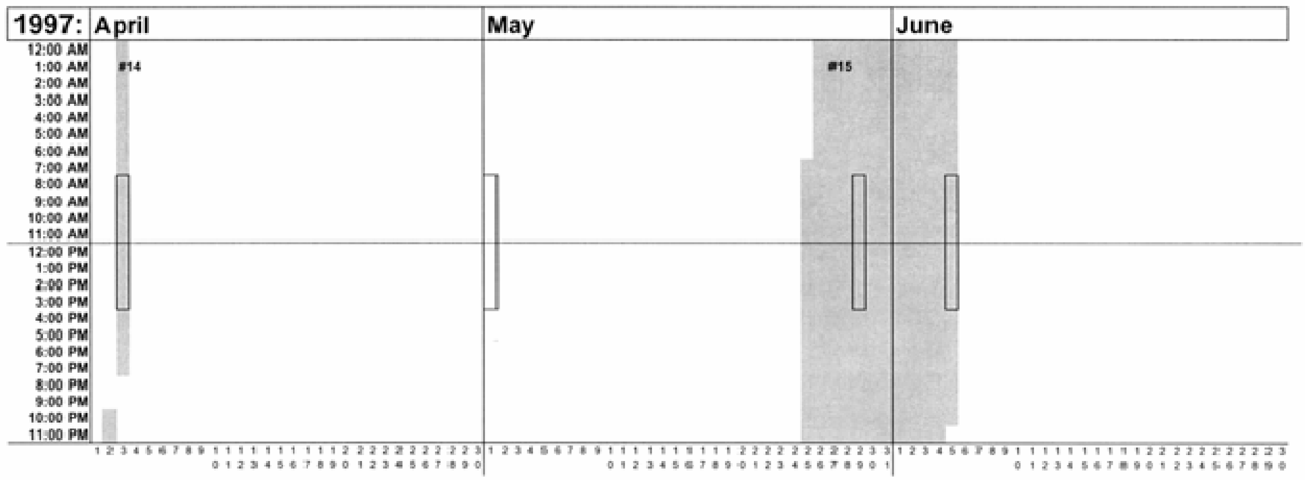
Outage #	Duration	Description
8	272:30	Power plant manually shutdown. Install SAIC instrumentation per direction from CERL. PMP400 and . FAN150 motor starters failed. Parts shipped



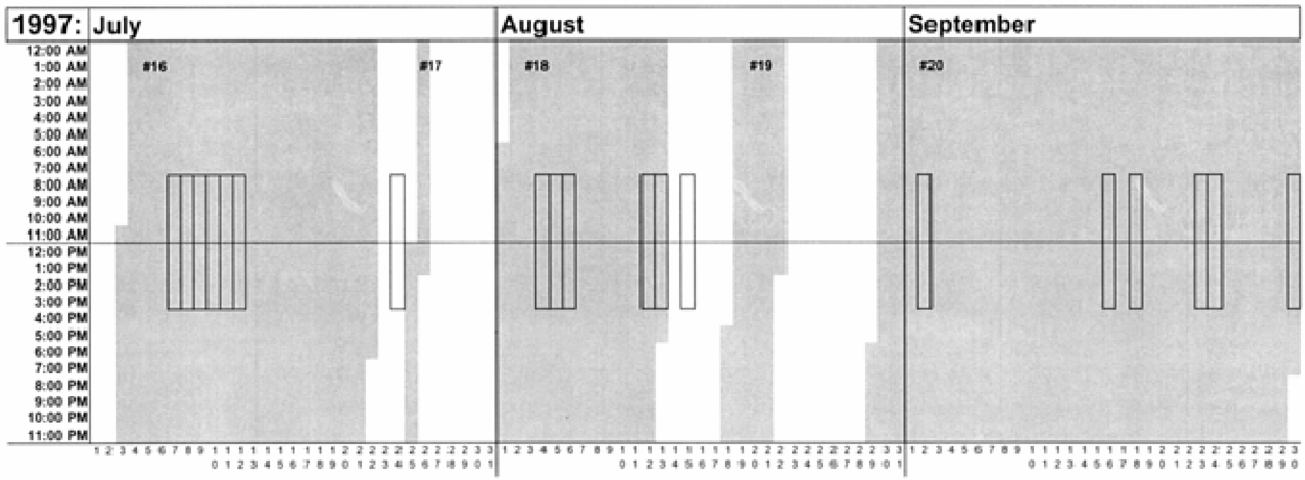
Outage #	Duration	Description
9	62:07	TMS: Power plant shutdown due to an indicated low coolant flow (FS400)
10	51:30	OTR: Power plant shutdown due to an interruption in gas supply



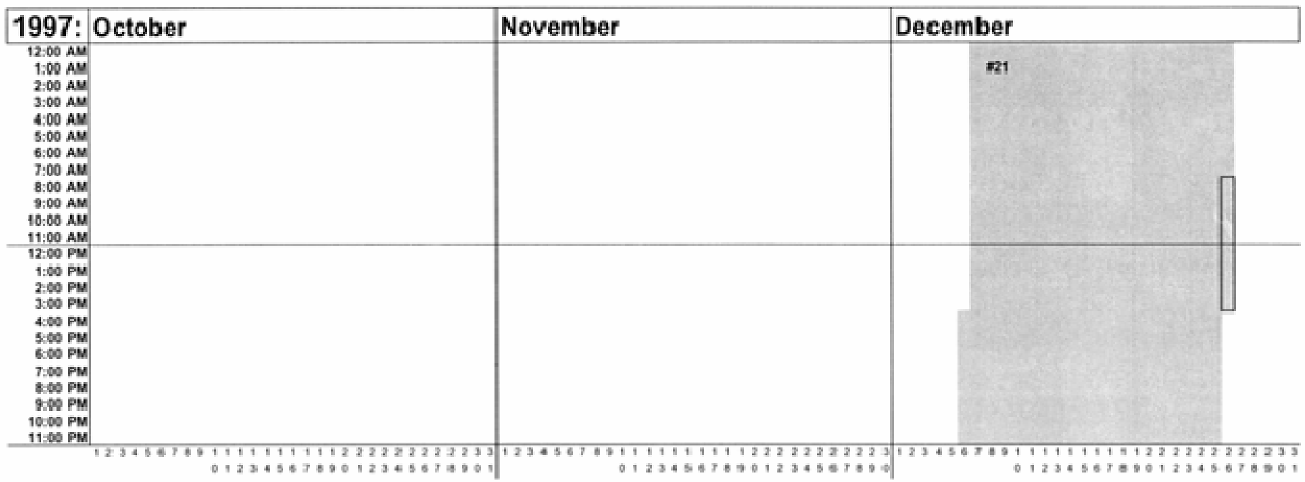
Outage #	Duration	Description
11	309:48	OTR: Power plant shutdown due to circuit breaker sequence error during grid event. Relay replaced.
12	13:45	OTR: P/P shutdown due to circuit breaker sequence error at time of grid disturbance.
13	20:12	OTR: P/P shutdown due to a plugged filter in the R/O unit.



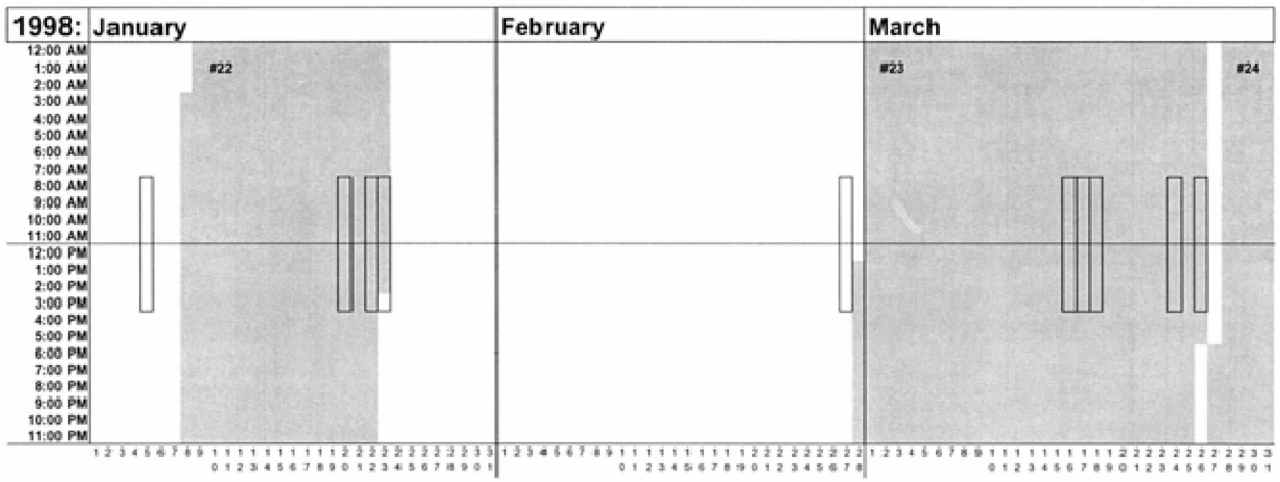
Outage #	Duration	Description
14	22:42	OTR: P/P manually shutdown to repair a water leak.
15	279:56	FPS: P/P shutdown due to a sticking fuel valve. Annual maintenance completed.



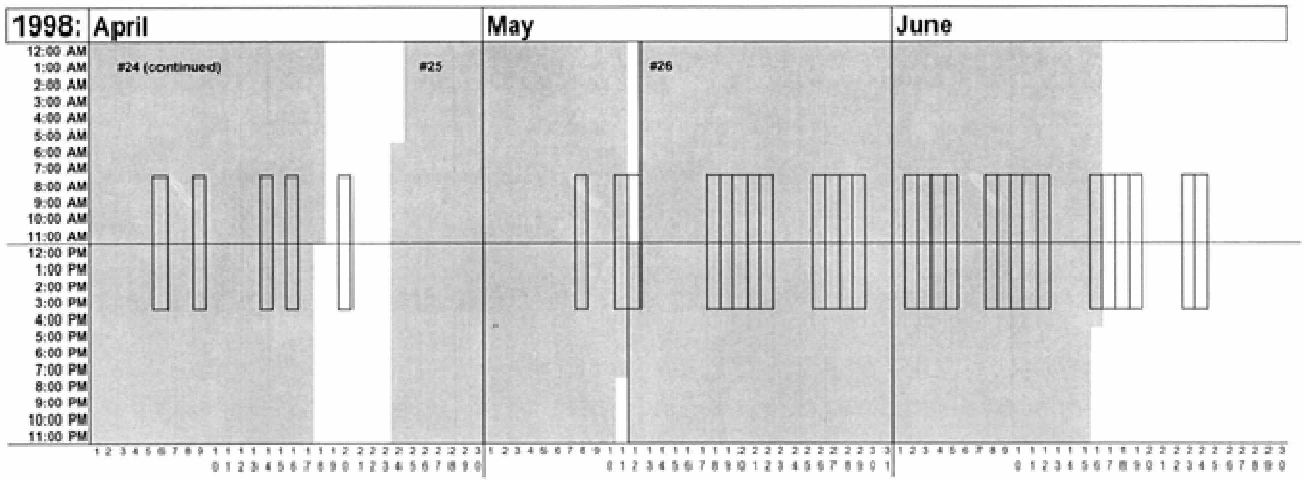
Outage #	Duration	Description
16	463:30	TMS: P/P shutdown due to high feed water temperature caused by back flow from the TMS. The shut-off valve, check valve, feed water pump, FT140, burner air valve and flow transmitter were replaced.
17	26:26	P/P manually shutdown to repair a site gas leak
18	298:40	OTR: P/P shutdown due to a logic card cage fan failure. Replaced PC5.
19	92:08	OTR: P/P shutdown due to a circuit breaker sequence error (K001).
20	782:08	ES: P/P shutdown due to a UPS failure. UPS batteries were replaced; PMP451 rebuilt.



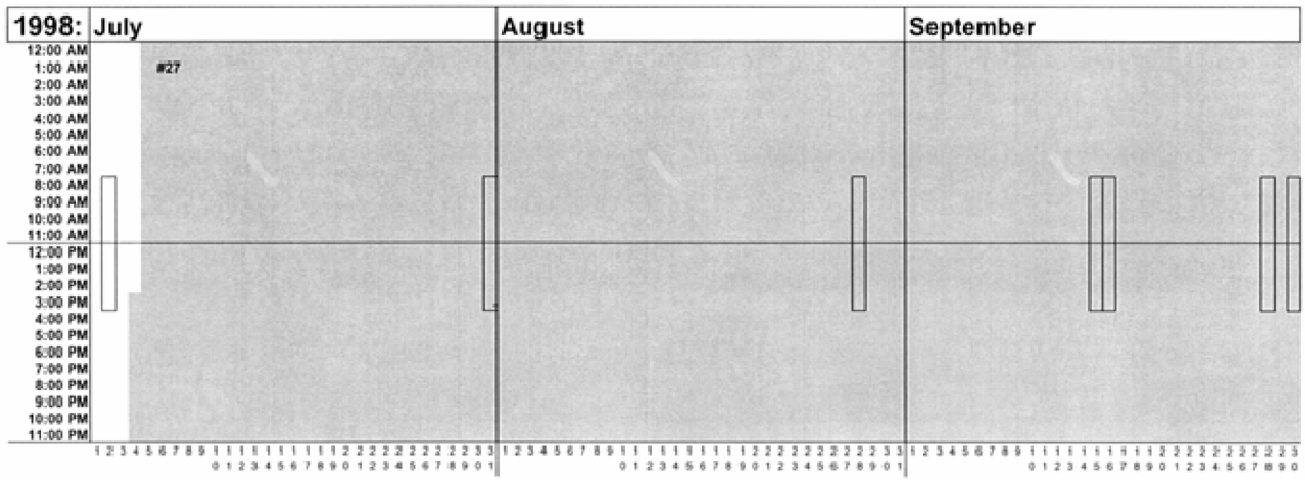
Outage #	Duration	Description
21	479:27	OTR: P/P shutdown due to a K002 sequencing error. Motorized circuit breaker adjusted.



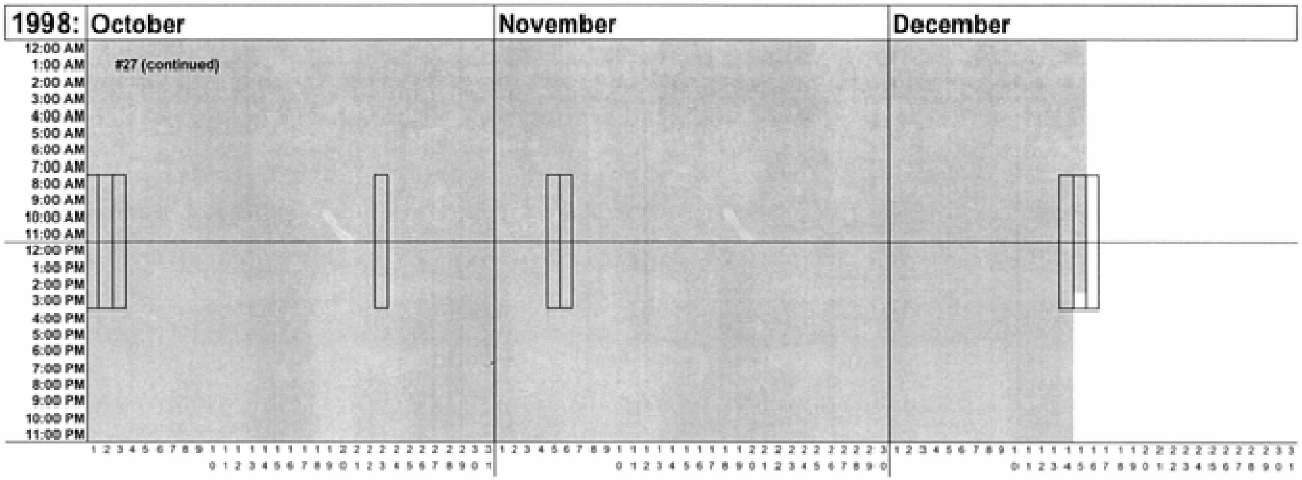
Outage #	Duration	Description
22	370:32	OTR: P/P shutdown due to low DC voltage. FCV012 replaced.
23	639:45	OTR: Maintenance activities involved circuit breakers K001, K002, and K003.
24	534:20	ES: Maintenance activities involved UPS replacement.



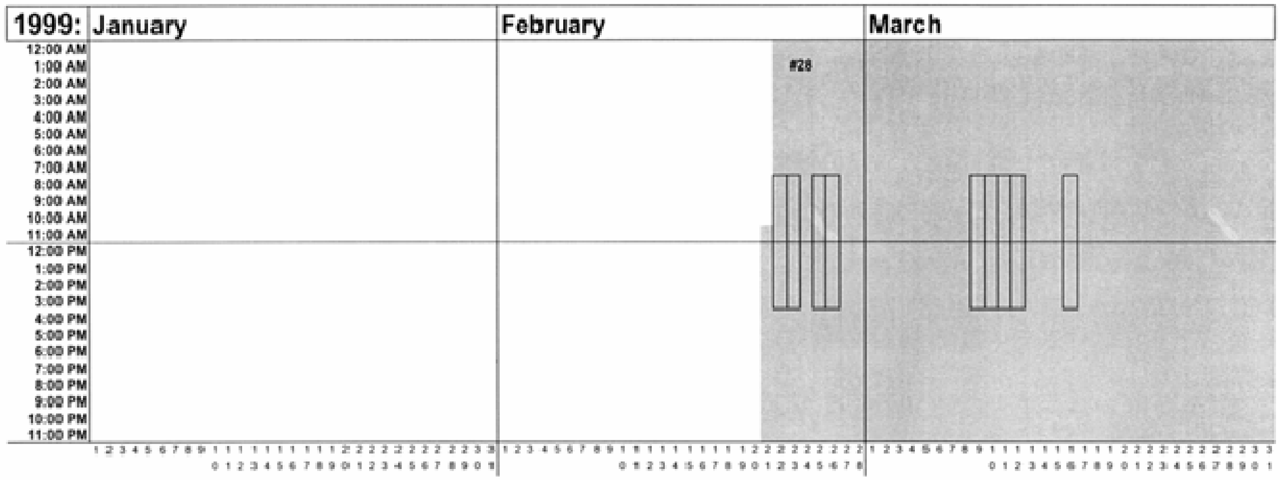
Outage #	Duration	Description
24	534:20	See previous page
25	422:10	TMS: Shutdown waiting to replace Hex's; replacement heat recovery flow meter on back order 6/5; replacement HEX430 & HEX431 ordered.
26	844:12	ES: P/P shutdown due to MCB002 error. Completed physical check of all wiring in motorized circuit breaker circuit. Fuel cell stack assembly was cleaned.



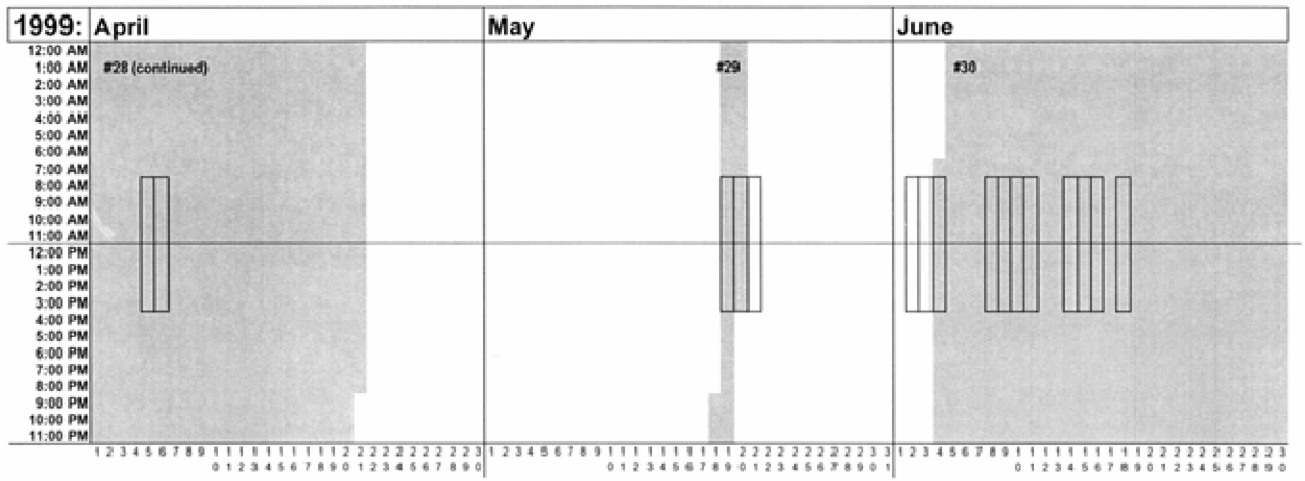
Outage #	Duration	Description
27	3,937:40	Manual power plant shutdown for site generator test; trouble shoot lockout relay issue 11/5; replacement heat recovery flow meter recovered; schedule replacement for HEX 430 & 431 for week of 9/28.



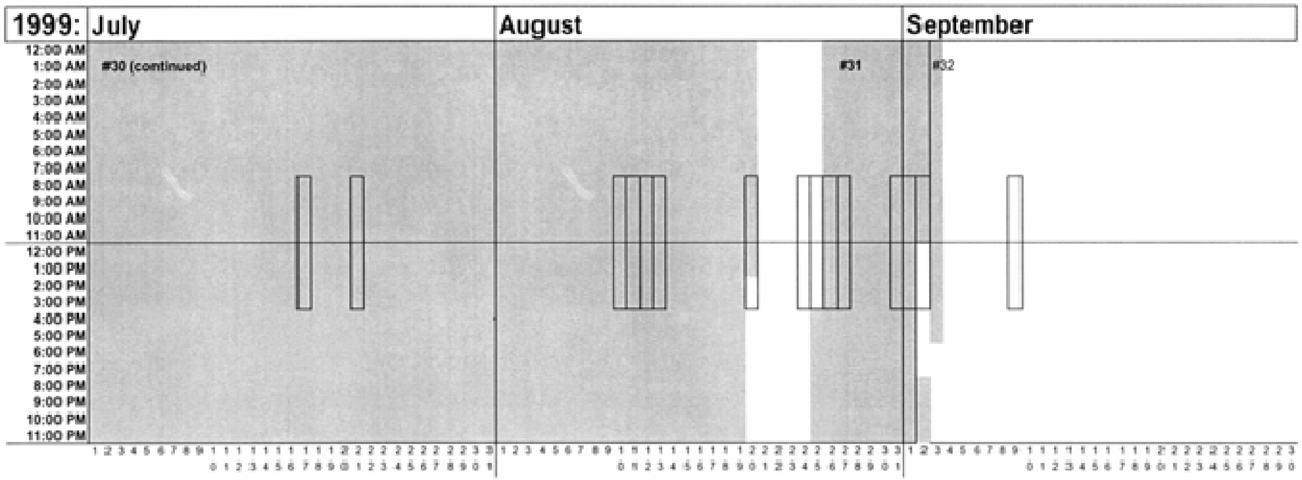
Outage #	Duration	Description
27	3,937:40	See previous page.



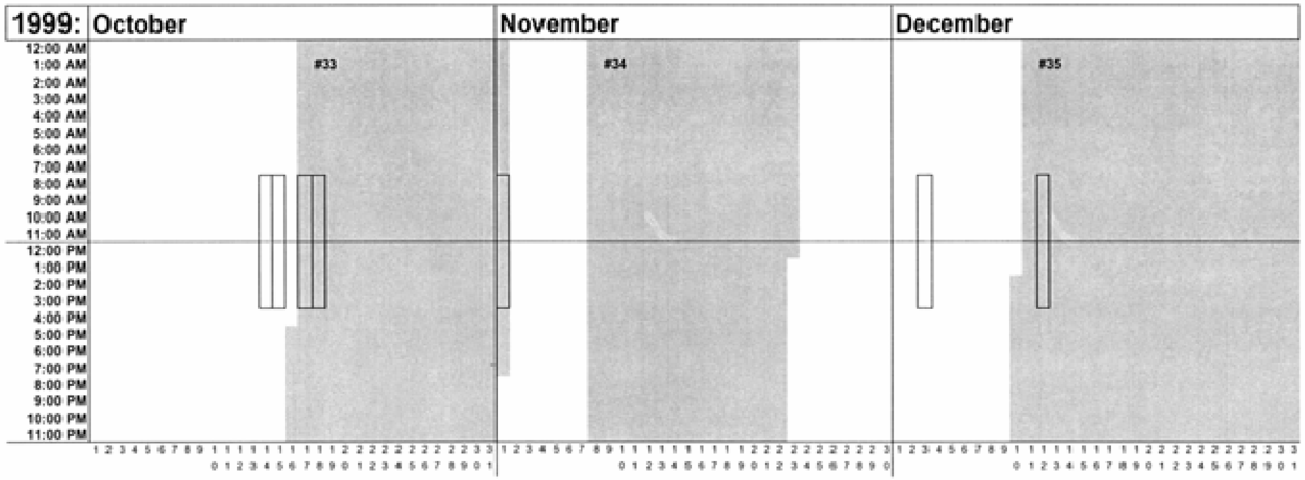
Outage #	Duration	Description
28	1,066:00	OTR: Shutdown on ground fault fuse.



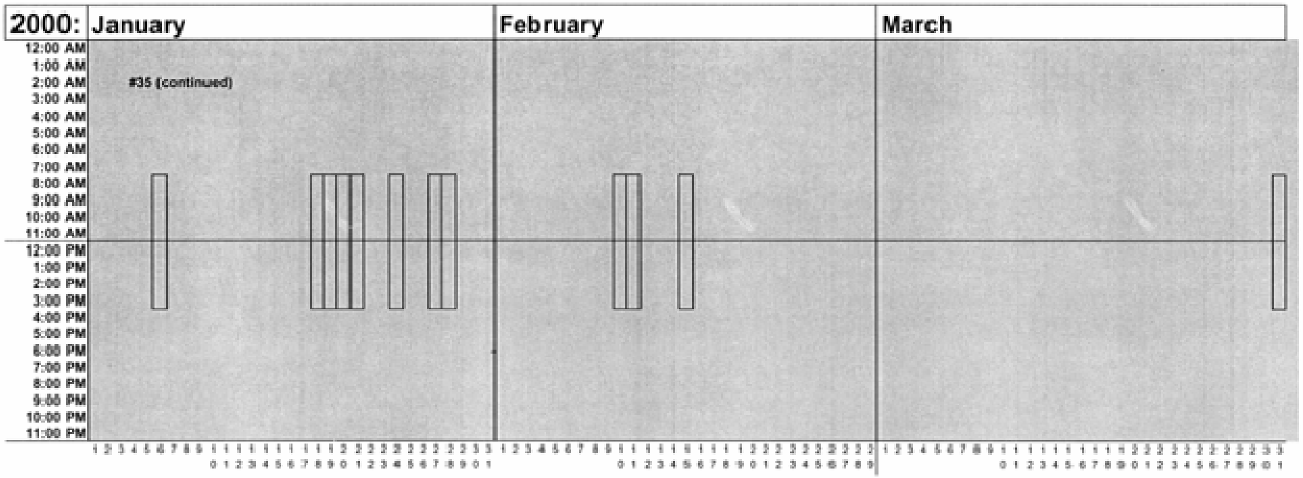
Outage #	Duration	Description
28	1,066:00	See previous page
29	43:10	APS: Hot shutdown on low flow transmitter FT140. Service rep successfully put plant in cool down state. CAUSE: leak in WTS system.
30	1,855:30	OTR: Replaced FT140, repaired leaking FO420, unsuccessful starts 6/10, 6/11, (got to idle) and 6/14, replaced I/O modules for FCV140, rebuilt TCV400 & replaced actuator, unsuccessful start 6/18



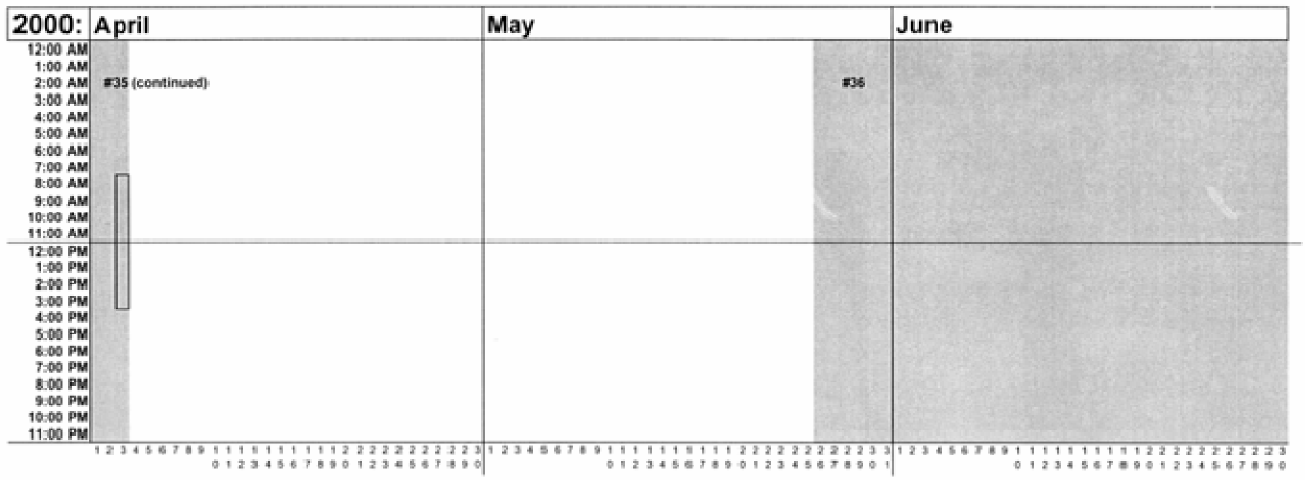
Outage #	Duration	Description
30	1,855:30	See previous page
31	188:09	APS: Shutdown on FT 140 low.
32	20:30	APS: Minimal information about outage, but probably same as outage #31.



Outage #	Duration	Description
33	400:00	WTS: Shutdown on loss of WTS water, FS450 off.
34	372:34	OTR: Shutdown on inverter sequence error.
35	514:18	TMS: Shutdown on FS400 off. Failed pump 400. Replacement sent.



Outage #	Duration	Description
35	514:18	See previous page.



Outage #	Duration	Description
35	514:18	See previous page.
36	Final Shutdown	

Appendix F: Summary of Maintenance Invoices by Year

Twentynine Palms Fuel Cell

Invoice	Labor		Nitrogen		Charcoal		Resin		Other Equipment		Travel	Shipping
Date	Hours	$	Cubic Feet	$	Cubic Feet	$	Cubic Feet	$	Part #	$	$	$
2-Nov-95	7.0	$315.00										
8-Nov-95	1.0	$45.00							Shipping			
16-Nov-95	1.0	$45.00	2432	$494.43					Cylinder Rental	$12.97		$34.00
11-Dec-95	1.0	$45.00										
11-Dec-95	9.0	$405.00										
13-Dec-95	2.5	$112.50										
28-Dec-95	1.0		2432	$693.24					Cylinder Rental	$19.41		
Totals	**22.5**	**$967.50**	**4,864**	**$1,187.67**	**0**	**$0.00**	**0**	**$0.00**		**$32.38**	**$0.00**	**$34.00**

Total Cost **$2,221.55**

Twentynine Palms Fuel Cell

Invoice Date	Labor Hours	Labor $	Nitrogen Cubic Feet	Nitrogen $	Charcoal Cubic Feet	Charcoal $	Resin Cubic Feet	Resin $	Other Equipment Part #	Other Equipment $	Travel $	Shipping $
Jan 13, 1996	2.0	$135.00							Misc.	$3.12		
Jan 14, 1996	2.0	$135.00										
Jan 26, 1996	5.0	$225.00										
Jan 29, 1996	8.5	$382.50										
Jan 30, 1996	10.0	$450.00							W.W. Grainger	$2,742.91		
Jan 31, 1996	10.5	$472.50							Misc.	$57.52		
Feb 02, 1996	11.0	$495.00							Diesel Fuel	$11.62		
Feb 03, 1996	10.0	$675.00							Diesel Fuel	$12.00		
Feb 05, 1996	9.0	$405.00							Misc.	$488.18		$116.05
Feb 06, 1996	18.0	$810.00							Cylinder Rental	$12.94		
Feb 08, 1996	26.0	$1,170.00	4864	$1,703.58					Crane Service	$1,275.00		
Mar 21, 1996	8.0	$360.00										
Mar 22, 1996	10.0	$450.00										
Mar 23, 1996	10.0	$675.00										
Mar 25, 1996	10.0	$450.00							Misc.	$264.30		
Mar 26, 1996	8.0	$360.00										
Mar 27, 1996	9.0	$405.00										
Mar 28, 1996	23.0	$1,035.00							Crane Service	$1,275.00		
Mar 29, 1996	8.0	$360.00										
Apr 01, 1996	9.0	$405.00										
Apr 02, 1996	17.0	$765.00							Misc.	$937.59		
Apr 03, 1996	14.0	$630.00										
Apr 09, 1996	9.5	$427.50										
Apr 10, 1996	10.0	$450.00										
Apr 11, 1996	14.0	$630.00										
Apr 12, 1996	10.0	$450.00										
Apr 15, 1996	7.5	$337.50										
Apr 16, 1996	6.0	$270.00										
Apr 17, 1996	10.0	$450.00							Welding	$135.00		
Apr 18, 1996	12.0	$540.00										
Apr 19, 1996	12.5	$562.50							Misc.	$378.93		
Apr 20, 1996	3.0	$202.50										
Apr 27, 1996	6.5	$438.75										
May 03, 1996	8.5	$382.50	3648	$343.92					Misc.	$315.37		
May 04, 1996	3.5	$236.25	3640	$222.22								
May 13, 1996	4.0	$180.00										
Jun 12, 1996	4.5	$202.50	3648	$278.02								
Jun 13, 1996	6.0	$270.00							Misc.	$163.24		
Jun 14, 1996	8.5	$382.50		$521.43					Misc.	$126.47		
Jun 17, 1996	6.5	$292.50										
Jun 18, 1996	5.0	$225.00							Misc.	$1,560.60		
Jun 19, 1996	6.5	$292.50										
Jul 08, 1996	9.0	$405.00										
Jul 09, 1996	9.0	$405.00										
Jul 10, 1996	9.0	$405.00		$497.16					Misc.	$309.61		
Jul 11, 1996	8.0	$360.00							Cell Phone	$199.28		
Jul 12, 1996	7.0	$315.00										
Jul 16, 1996	7.5	$337.50										
Jul 17, 1996	9.0	$405.00							Cylinder Rental	$6.47		
Jul 18, 1996	14.0	$630.00							Misc.	$1,015.65		
Jul 19, 1996	7.0	$315.00	1216	$250.22								
Aug 09, 1996	9.5	$427.50		$561.02					Misc.	$224.77		$5.89
Aug 22, 1996	6.0	$270.00		$596.47					Misc.	$147.85		
Sept. 1996				$825.59	2	$186.00	10	$2,180.00	Misc.	$65.94		
Nov 04, 1996	4.0	$200.00										
Nov 06, 1996	8.0	$400.00										
Nov 07, 1996	2.0	$100.00										
Nov 12, 1996	8.0	$400.00										
Nov 13, 1996	1.0	$50.00		$295.50	2	$186.00	10	$2,650.00	Cell Phone	$75.00		
Dec 03, 1996	6.0	$300.00		$364.20			21	$5,565.00	Cell Phone	$72.90		
Dec 07, 1996	8.0	$400.00		$357.38					Misc.	$269.41		
Totals	**605.0**	**$24,597.50**	**17016**	**$6,459.33**	**4**	**$372.00**	**41**	**$10,395.00**		**$11,877.26**	**$0.00**	**$121.94**

Total Cost $53,823.03

Twentynine Palms Fuel Cell

Invoice Date	Labor Hours	Labor $	Nitrogen Cubic Feet	Nitrogen $	Charcoal Cubic Feet	Charcoal $	Resin Cubic Feet	Resin $	Other Equipment Part #	Other Equipment $	Travel $	Shipping $
Jan 17, 1997	9.0	$450.00										
Jan 18, 1997	7.0	$350.00										
Jan 21, 1997	11.5	$575.00										
Jan 22, 1997	12.0	$600.00										
Jan 23, 1997	8.0	$400.00										
Jan 24, 1997	6.0	$300.00										
Jan 27, 1997	1.0	$50.00										
Jan 28, 1997	10.0	$500.00										
Feb 08, 1987	7.5	$375.00		$306.00					Cylinder Rental	$19.41		
Mar 11, 1997	9.0	$450.00			2	$186.00	16	$3,616.00				
Mar 12, 1997	7.0	$350.00		$600.54								
Apr 03, 1997	10.0	$500.00		$804.96					Misc.	$69.17		
May 01, 1997	3.5	$175.00		$403.00								$165.75
May 29, 1997	2.0	$100.00		$848.84					Cylinder Rental	$6.47		
Jun 05, 1997	36.0	$1,800.00		$737.30	2	$186.00	11	$2,486.00	Misc.	$271.16		$41.71
Jul 07, 1997	5.0	$250.00										
Jul 08, 1997	5.0	$250.00										
Jul 09, 1997	7.0	$350.00										
Jul 10, 1997	2.0	$100.00										
Jul 11, 1997	5.0	$250.00										
Jul 12, 1997	7.0	$350.00										$30.00
Jul 24, 1997	4.0	$200.00										
Aug 04, 1997	4.0	$200.00										
Aug 05, 1997	8.0	$400.00		$620.96								
Aug 06, 1997	6.0	$300.00							Welding	$100.00		
Aug 12, 1997	5.0	$250.00							Cylinder Rental	$25.88		
Aug 13, 1997	8.0	$400.00							Misc.	$110.00		
Aug 15, 1997	4.5	$225.00		$549.34					Misc.	$76.71		$50.79
Sep 02, 1997	1.0	$50.00							Misc.	$59.66		$177.00
Sep 16, 1997	7.5	$375.00										
Sep 18, 1997	7.5	$375.00										
Sep 23, 1997	8.0	$400.00										
Sep 24, 1997	7.5	$375.00		$752.82					Cell Phone	$248.00		
Sep 30, 1997	4.0	$200.00		$399.75								
Nov 1997									Batteries	$498.94		$106.41
Dec 26, 1997	4.0	$200.00		$398.03								
Totals	249.5	$12,475.00	0	$6,421.54	4	$372.00	27	$6,102.00		$1,485.40	$0.00	$571.66

Total Cost $27,427.60

Twentynine Palms Fuel Cell

Invoice	Labor		Nitrogen		Charcoal		Resin		Other Equipment		Travel	Shipping
Date	Hours	$	Cubic Feet	$	Cubic Feet	$	Cubic Feet	$	Part #	$	$	$
Jan 05, 1998	3.0	$150.00		$240.55								
Jan 20, 1998	17.0	$850.00										
Jan 22, 1998	7.0	$350.00							Cylinder Rental	$6.47		$20.88
Jan 23, 1998	11.0	$550.00										
Feb 27, 1998	8.0	$400.00			2	$ 186.00	8	$1,808.00	Cylinder Rental	$12.94		
Mar 16, 1998	6.0	$300.00										
Mar 17, 1998	8.5	$425.00		$339.95								$42.90
Mar 18, 1998	1.0	$50.00							Cylinder Rental	$6.47		
Mar 24, 1998	6.0	$300.00							Misc.	$1.33		
Mar 26, 1998	13.0	$650.00										
Apr 06, 1998	2.0	$100.00										
Apr 09, 1998	16.0	$800.00										$70.70
Apr 14, 1998	3.0	$150.00										
Apr 16, 1998	5.5	$275.00		$471.31					Misc.	$16.99		
Apr 20, 1998	3.0	$150.00		$314.65			2	$452.00	Cylinder Rental	$6.47		
May 08, 1998	4.0	$200.00										
May 11, 1998	12.0	$600.00							Misc.	$82.29		
May 12, 1998	4.0	$200.00		$142.39								
May 18, 1998	10.0	$500.00										
May 19, 1998	16.0	$800.00										
May 20, 1998	19.0	$950.00										
May 21, 1998	2.0	$100.00										
May 22, 1998	10.0	$500.00		$215.85					Misc.	$10.80		
May 26, 1998	6.0	$300.00										
May 27, 1998	12.0	$600.00							Cylinder Rental	$6.47		
May 28, 1998	9.0	$450.00							Misc.	$29.62		
May 29, 1998	10.0	$500.00										
Jun 02, 1998	6.0	$300.00										
Jun 03, 1998	8.0	$400.00							Welder	$75.00		
Jun 04, 1998	12.0	$600.00		$136.79					Misc.	$48.87		
Jun 05, 1998	7.0	$350.00										
Jun 08, 1998	8.0	$400.00										
Jun 09, 1998	13.0	$650.00							Misc.	$34.25		
Jun 10, 1998	7.0	$350.00										
Jun 11, 1998	8.5	$425.00										
Jun 12, 1998	4.0	$200.00										
Jun 16, 1998	8.0	$400.00										
Jun 17, 1998	5.0	$250.00										
Jun 18, 1998	2.0	$100.00										
Jun 19, 1998	4.0	$200.00			2	$186.00	8	$1,808.00				
Jun 23, 1998	12.0	$600.00		$244.20					Misc.	$138.48		
Jun 24, 1998	5.5	$275.00		$215.85								
Jul 02, 1998	2.0	$100.00		$133.35					Cylinder Rental	$6.47		
Jul 31, 1998	2.0	$100.00										$72.40
Aug 28, 1998	2.0	$100.00		$299.18					Misc.	$197.94		$28.00
Sep 15, 1998	1.0	$50.00										
Sep 16, 1998	2.0	$100.00										
Sep 28, 1998	2.0	$100.00										
Sep 30, 1998	4.5	$225.00										
Oct 01, 1998	9.5	$475.00							Cylinder Rental	$12.94		
Oct 02, 1998	9.0	$450.00							Misc.	$158.93		
Oct 03, 1998	4.5	$225.00		$207.15					Welder	$850.00		
Oct 23, 1998	2.0	$100.00										
Nov 05, 1998	2.0	$100.00										
Nov 06, 1998	2.0	$100.00							Cylinder Rental	$6.47		
Dec 14, 1998	4.5	$225.00										
Dec 15, 1998	10.5	$525.00		$139.20								
Dec 16, 1998	8.0	$400.00							Cylinder Rental	$6.47		$69.00
Totals	401.5	$20,075.00	0	$3,100.42	4	$372.00	18	$4,068.00		$1,715.67	$0.00	$303.88

Total Cost $29,634.97

Year #4: 1998

Twentynine Palms Fuel Cell

Invoice Date	Labor Hours	Labor $	Nitrogen Cubic Feet	Nitrogen $	Charcoal Cubic Feet	Charcoal $	Resin Cubic Feet	Resin $	Other Equipment Part #	Other Equipment $	Travel $	Shipping $
Jan 1999				$143.84					Cylinder Rental	$6.47		
Feb 1999				$233.85					Cylinder Rental	$6.47		
Feb 22, 1999	4.0	$200.00										
Feb 23, 1999	6.0	$300.00										
Feb 23, 1999	11.0	$550.00							Misc.	$29.43		
Feb 25, 1999	6.0	$300.00										
Feb 26, 1999	7.0	$350.00										
Mar 09, 1999	10.0	$500.00										
Mar 10, 1999	9.0	$450.00										
Mar 11, 1999	4.0	$200.00										
Mar 12, 1999	2.0	$100.00							Cylinder Rental	$6.47		
Mar 16, 1999	11.0	$550.00		$129.92					Misc.	$81.13		
Apr 05, 1999	4.0	$200.00							Cylinder Rental	$6.47		
Apr 06, 1999	18.0	$900.00		$238.55					Misc.	$179.39		
May 19, 1999	1.0	$55.00										
May 20, 1999	12.0	$705.00		$139.20					Cylinder Rental	$12.94		
May 21, 1999	3.5	$192.50			2	$186.00	8	$2,080.00	Misc.	$61.53		
Jun 02, 1999				$238.55					Misc.	$1,131.94		
Jun 04, 1999	7.0	$385.00										
Jun 08, 1999	2.0	$110.00										
Jun 09, 1999	3.0	$165.00							Welding	$125.00		
Jun 10, 1999	6.0	$330.00										
Jun 11, 1999	8.0	$440.00										
Jun 14, 1999	9.0	$495.00							Cell Phone	$60.98		
Jun 15, 1999	6.5	$357.50										
Jun 16, 1999	7.5	$412.00										
Jun 18, 1999	13.0	$752.50										
Jul 17, 1999	1.0	$55.00		$374.97					Cell Phone	$57.48		
Jul 21, 1999	2.0	$110.00		$304.00					Cylinder Rental	$6.47		
Aug 10, 1999	8.0	$440.00							Cylinder Rental	$157.81		
Aug 11, 1999	12.0	$660.00										
Aug 12, 1999	9.0	$495.00										
Aug 13, 1999	5.5	$302.00									$42.34	
Aug 20, 1999	8.0	$440.00		$553.89								
Aug 24, 1999	7.0	$385.00										
Aug 25, 1999	8.0	$440.00										
Aug 26, 1999	10.0	$550.00										
Aug 27, 1999	5.0	$275.00										
Aug 31, 1999	13.0	$715.00		$514.05								
Sep 01, 1999	4.0	$220.00							Cylinder Rental	$6.47		
Sep 02, 1999	8.0	$440.00							Misc.	$11.05	$91.59	
Sep 09, 1999	3.0	$165.00			2	$206.00	8	$2,160.00				
Oct 14, 1999	2.0	$110.00										
Oct 15, 1999	2.0	$110.00										
Oct 17, 1999	1.0	$55.00							Misc.	$13.20		
Oct 18, 1999	2.0	$110.00		$414.62					Cylinder Rental	$304.51		
Nov 01, 1999	9.0	$495.00							Cylinder Rental	$6.47	$20.07	
Dec 03, 1999	2.0	$110.00							Misc.	$124.19		
Dec 12, 1999	1.0	$90.00							Cylinder Rental	$231.38		
Totals	293.0	$15,771.50	0	$3,285.44	4	$392.00	16	$4,240.00		$2,627.25	$154.00	$0.00

Total Cost $26,470.19

Year #5: 1999

Maintenance Summary

Twentynine Palms Fuel Cell

Invoice Date	Labor Hours	Labor $	Nitrogen Cubic Feet	Nitrogen $	Charcoal Cubic Feet	Charcoal $	Resin Cubic Feet	Resin $	Other Equipment Part #	Other Equipment $	Travel $	Shipping $
Jan 06, 2000	1.0	$55.00		$330.72					Cell Phone	$17.21		
Jan 18, 2000	1.0	$55.00										
Jan 19, 2000	6.0	$330.00										
Jan 20, 1999	8.5	$467.50							Misc.	$44.29		
Jan 21, 2000	8.0	$440.00							Cylinder Rental	$6.47		
Jan 24, 2000	9.5	$522.50										
Jan 27, 2000	8.0	$440.00							Misc.	$22.33		
Jan 28, 2000	5.0	$275.00							Cylinder Rental	$142.06		
Feb 10, 2000	7.0	$385.00										
Feb 11, 2000	6.0	$330.00		$546.28					Misc.	$12.21		
Feb 15, 2000	5.0	$300.00		$140.90					Cylinder Rental	$6.47	$32.95	
Mar 31, 2000	3.0	$165.00							Cylinder Rental	$167.48		
Apr 03, 2000	8.5	$467.50							Cylinder Rental	$218.00		
May 2000									Cylinder Rental	$188.08		
Jun 2000									Cylinder Rental	$194.03		
Jul 2000									Cylinder Rental	$212.95		
Jul 2000									Misc.	$28.85		
Aug 2000									Cylinder Rental	$168.16		
Sep 2000									Cylinder Rental	$231.61		
Oct 2000									Cylinder Rental	$85.92		
Totals	76.5	$4,232.50	0	$1,017.90	0	$0.00	0	$0.00		$1,746.12	$32.95	$0.00

Total Cost $7,029.47

Year #6: 2000

Maintenance Summary

Appendix G: Project Meeting Notes

DARRYL MATSUI
BEN'S CRANK
STU HAMMONS
LUKE WREN

PAT DOUGHERTY
HOSPITAL FACILITY MANAGER

08 DEC 93
29 PALMS

Roberts Construction

ELEC – SO CAL EDISON (WAYNE ~~HOFSTEAD~~ HOFELDT – MILITARY BASE 369-5425 (YUCCA VALLEY)

GAS – SOCAL GAS (ALSO SOME ~~DRES~~ DSSC – CAMERON STATION)

↳ TOU B RATE

SOCAL GAS POC (TERRANCE MACK).

DIESEL FUEL OIL IS ONLY OTHER FUEL ALLOWED BY CALIFORNIA LAW – IT IS BACK UP FUEL FOR HOSPITAL (EMERGENCY GENERATOR USE #2 DIESEL).

CENTRIFUGAL CHILLERS IN HOSPITAL.

HOSPITAL WAS SUPPOSED TO GO ON LINE IN NOVEMBER 1992 BUT WASN'T OCCUPIED UNTIL AROUND MARCH 1993.

3 – 1000 kW Diesel Generators

ENSIGN TIFFANY MONACO
Naval Hospital, 29 Palms
(619) 830-2395

PRIMARY POC FOR HOSPITAL (MAINTENANCE OFFICER)

Scott • NREA • ext. ~~5624~~
Mojave Des. AQ Mgt. Dist
Victorville, Ca.
Richard Wales.
Air Qual. Engr.
#(619) 245-5402

(Chris Collins)

29 Palms - Kick off meeting) 03 MAY 94

1/

EMERGENCY GENERATOR TIE IN ?

WEEKLY/MONTHLY TESTS ON GENERATORS REQUIRED. FUEL CELL MAY HAVE TO BE INCLUDED IN TEST.

IF GRID LOST - Generators Come on. FUEL CELL DOES NOT RECONNECT UNTIL Grid is up - Requires Manual restart (9 sec. delay on emergency generators).

* Follow up on Anaheim Hospital fuel cell visit.

ONSI's COMMENTS:

(1) MAJOR COST OF INSTALLATION ⇒ PIPING (& THERMAL LOSSES)

Doug YOUNG - HOW DATA MONITORING WORKS.

TOU STANDBY RATE - WAYNE WILL SEND TO ME.

HOSPITAL Expansion (Ensign to check w/ Jim Jenson / NAVFAC-SWDIV)

ONSITE Review Meeting - Get SW involved - If not, Public Works would do review (HOWARD Devore).

Could hook into Galley for emergency backup without interfacing with generators (Extra Manhole access conduits).

ROSTER FOR 09 DEC 93 MEETING ON "FUEL CELL"

NAME	POSITION	AGENCY
. MONACO	FACILITIES OFFICER	NHTP
M J. ROMAN	XO	NHTP
S. D. HAMMONS	FAC. MAINT. UTIL. ENGR.	MCAGCC
GERRY MERTEN	Div. Mgr	SAIC
MIKE BINDER	PRINCIPAL INVESTIGATOR	USACERL (CECER-FEP)
T C.R. MIRANDA	Facilities (MCLO) pro tem	NAVHOSP T.P.
Patrick Dougherty	Fac. Maint. Off.	NHTP
CDR Brannon	DFA	NHTP
E.P. THOMPSON	Asst Fac Maint O	NHTP

29 PALMS MCB DESIGN REVIEW 02 MAR 95

LT. DUFOUR - ROICC COORDINATOR FOR PROJECT

DRAWING REVISIONS GIVEN TO BASE/HOSPITAL FROM USACERL/SAIC REVIEW

GENERAL TIME FRAME/PROCEDURES FROM HERE TO RIBBON CUTTING.

PRESENTATION OF DESIGN - DOUG YOUNG (ONSI)

DRAWINGS: (1st Go-Through - Original design
(2nd Go-Through - Modifications per our Comments [Revised drawings])

S1 - FOUNDATION LAYOUT
S2 -
ME 1 - Rev 1
M1 - REV 1 (105°F & 140°F DHW Supply)
M2 - NEW DRAWING
E-1 - ELECTRICAL WIRING
(500-520 V COMMON AT HOSPITAL-BASE TO INSTALL VOLTAGE REGULATOR IN SUMMER-FUEL CELL WILL DROP OFF GRID AT 528V)
-GALLEY IS ON GRID INDEPENDENT (DEDICATED LOAD) TERMINALS
- DESCRIPTION OF MONITORING/COMMUNICATION FOR O&M OF FCPP
E-2 Rev 1
E-3
M 114 MARKUP OF HOSPITAL DRAWING

M122 - MARKUP OF HOSPITAL DRAWING

ACTION ITEM - MOVE 105°F & 140°F
Recirc lines to just after P2 to
increase thermal recovery - Didn't do
originally ~~to~~ because of long pipe runs
but with new fuel cell location it looks
pretty short.

⇒ JOE STANIUNAS TO LOOK AT
THIS - IF WE DECIDE THAT, THE
AS-BUILTS WILL REFLECT THIS.

SEE LETTER OF RESOLUTION FROM LNSI

TAKE ANOTHER POWER MEASUREMENT
TO DETERMINE IF WHOLE Galley can
run ON FCPP (< 200 kw), Then Note
ON E1 ABOUT Selected Normal
Circuits to be powered will be
removed.

⇒ Put recorder on Galley circuit
to verify peak loads.
George will Supply Recorder and
Coordinate with Base Personnel.

SEE ACCEPTANCE TEST NOTES

Discussion of CERL/SAIC Comments & How Revisions Address them.

Drawing E-1 2" } Piping from Storage Tank
M-1 3"
ME-1 2"

⇒ Check and correct discrepancy

⇒ (Also 4" DiA on M-1 should be 4' dia Storage tank). Correct on drawing (also possibly on another drawing as well - Check *)

SAIC Comment #4 - Note to check for backflow added to M-1 Rev 1 (Steve ⇒ Probably won't need one). CHECK TO MAKE SURE.

⇒

SAIC Comment 5 Electrical (Actually 7).

a. No PE Electrical Available in high desert area. ⇒ Base will not require stamp

b } E-2 Rev 1 handles
c }

d } ME-1 handles

ME-1 Rev 1 Can move connection to existing gas supply to left (closer to fuel cell) to cut down on piping. Check on this. [Also Change 3' line to 3" line on ME-1 Rev-1.] Regulator needed in either case to drop pressure down to FCPP requirements.

SAIC ELECT COMMENTS
(e) Drawing E-3 handles
(f) ME-1 Rev 1 handles

ENSIGN MONACO:

S-2 & S-1 Grade slopes toward hospital as well as ⊥ to hospital - Drain required on hospital side of concrete slab.

⇒ BASE NEEDS TO CONTACT BASE Phone to get 2 PAIR Phone line Connection (Request to be done by Ensign Monaco).

Authorization to Proceed as per results of pre construction meeting (to ONSI)

ONSI Comments to me by next Thursday morning so I can draft letter to ONSI. Public Works to draft letter today.

PRE Construction Meeting on Weds 08 MAR
with George & Hospital/Base personnel
TIME 0900.

Construction Starts Monday 13 MAR (Subject to results of preconstruction meeting)

Spot Gas vs. SoCal Gas ($2.10/MBTU vs. ~ $6.00 MBTU). Check with SW DIV on whether line could be run for spot gas.

⇒ Check with Dave Winn or Max Sheh.

Does SoCal Gas have Cogen rate? (Terrence Mach is POC at SoCAL)?

Base to take photographs during Construction.

<u>NOTE:</u> DHW MAKUP IS THE ONLY THERMAL INTERFACE THAT WILL BE USED.

29 PALMS MCB – ACCEPTANCE TEST 23 JUN 95

I. INTRO – PURPOSE OF MEETING (ACCEPTANCE TEST REPORT, INSTALLATION VS DESIGN, ACCURACY OF AS-BUILTS, SITE WALK THROUGH, DD FORM 250, DEDICATION ~~SCHEDULE~~ TRAINING CEREMONY DISCUSSION, CONSTRUCTION PICTURES/INTERNAL NOTES)

II. ACCEPTANCE TEST REPORT – DOUG YOUNG
- OVERVIEW OF ACCEPTANCE TEST PROCEDURE
- DISCUSSION OF ACTUAL SCREEN DISPLAYS (IDLE STATE) – VERY DETAILED DESCRIPTION OF EACH DATA ITEM.
- REVIEW OF ALL OTHER ~~SETS~~ POINTS DATA SCREENS.
  - GRID DEPENDENT
  - GRID INDEPENDENT

III. AS-BUILT DRAWINGS OF FUEL CELL (RECORD DRAWINGS) – DOUG YOUNG
- LIST OF CHANGES FROM DESIGN DRAWINGS,
  [NOTE: ENTIRE GALLEY IS POWERED BY FUEL CELL – NOTE ON E-1 ABOUT SELECTED CIRCUITS TO BE REMOVED FROM AS-BUILTS.

IV. MARKED UP HOSPITAL DRAWINGS – GEORGE GILLARD

V. ACTION ITEMS
- FIX NOTE ON DRAWING E-1
- PHYSICALLY POSITION COLD WATER FEEDLINE TO POSITION AS SHOWN ON M-1

-2-

- CHANGE HOSPITAL MARK UP DRAWINGS TO REFLECT CHANGE OF COLD WATER INLET LOCATION (PER PREV NOTE.)
- KIRK-KEY SYSTEM TO BE DELIVERED BY SQUARE D
- KEY TO FENCE CHAIN & LOCK KEYED TO MR3.
- EXTENSIVE CALLS MADE DURING START UP - BILL TO BE PAID BY ONSI
- ONSI WILL REPLACE STOLEN NOTEBOOK COMPUTER
- Sheet Metal holes to be cut in penetrations.

NOTES:

- IF UTILITY LOST, GOES TO IDLE 1 SECOND, THEN TO GRID INDEPENDENT.
- IF GRID COMES BACK FOR 15 sec, GRID CONNECT MODE REESTABLISHED
- IF GRID OUT FOR MORE THAN 3200 seconds, Manual ReConnect is required (Fuel Cell won't automatically reconnect).
- DURING GENERATOR TESTS, FUEL CELL WILL PARTICIPATE IN TEST (GRID SHUT OFF AUTOMATICALLY)
- TRAINING COMPLETE
- CONSTRUCTION PHOTOS - Lt Monaco
- CONSTRUCTION NOTES - George to Provide

-3-

~~WEEK OF 17 JUL~~

— THURSDAY 20 JUL for DEDICATION CEREMONY (9:00 am) (Lt Monaco to Confirm)

* — CONTACT DANA ABOUT 95%. Electric Power + ABOUT PRESS Coverage

* — CALL & INVITE DICK WALSH TO ATTEND.

* — QUESTION ABOUT PROJECT NEPA DOCUMENTATION. (CHECK WITH BILL — IF ONE EXISTS 29 Palms would like one on file).

Appendix H: Fuel Cell Photographs

DSCF0102.JPG

DSCF0103.JPG

DSCF0104.JPG

DSCF0105.JPG

DSCF0108.JPG

DSCF0109.JPG

DSCF0110.JPG

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Naval Hospital at Marine Corps Air Ground Combat Center – Twentynine Palms

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5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
J. Michael Torrey, John F. Westerman, William R. Taylor, Franklin H. Holcomb, and Joseph Bush

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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14. ABSTRACT

Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. In fiscal year 1993 (FY93), the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was assigned the mission of managing the DOD Fuel Cell Demonstration Program. Specific tasks included developing turnkey PAFC packages, devising site criteria, screening candidate DOD installation sites based on selection criteria, evaluating viable applications at each candidate site, coordinating fuel cell site designs, installation and acceptance of the PAFC power plants, and performance monitoring and reporting.

CERL selected and evaluated 30 application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to fuel cell manufacturers. At the conclusion of the demonstration period, each of the demonstration fuel cell sites was given the choice to either have the fuel cell removed or to keep the fuel cell power plant. This report presents a detailed review of a 200 kW fuel cell installed at the Marine Corps Air Ground Combat Center (MCAGCC) – Twentynine Palms and operated between June 1995 and May 2000.

15. SUBJECT TERMS
fuel cells; energy conservation; energy technology alternatives; Twentynine Palms

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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